Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6

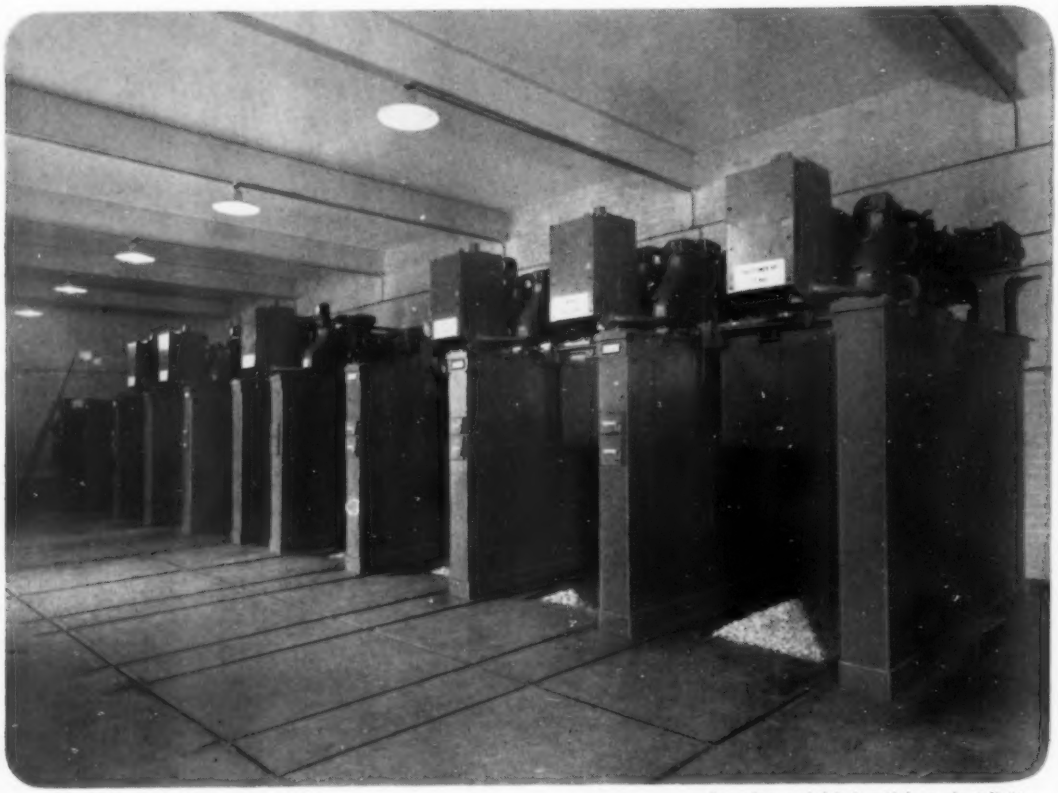
SEPTEMBER 1956

TEXAS TECNHNOLOGICAL
OCT 12 1956
COLLEGE

G.E.C.

HYDRO-ELECTRIC PLANT

METALCLAD SWITCHGEAR'S JUBILEE



A modern metalclad switchgear installation

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Reyrolle installed the first horizontal drawout metalclad switchgear in the World at Swan Hunter's Shipyard Wallsend. Experience over the intervening years has proved the soundness of the basic principles which are still incorporated in modern designs. Research and testing facilities have led to the introduction of refinements that have kept Reyrolle Switchgear pre-eminent in this important field of electrical engineering. As switchgear specialists we are at your service.

Reyrolle

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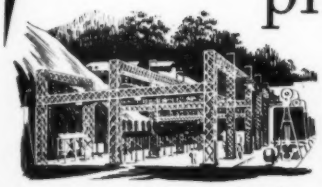
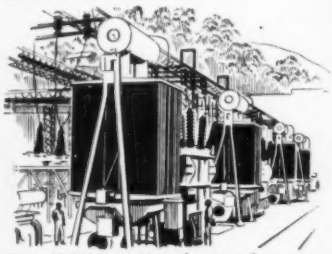
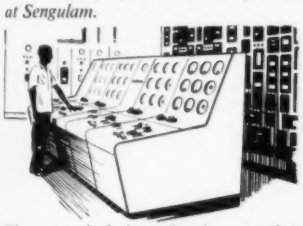
Comprehensive hydro-electric project at Sengulam



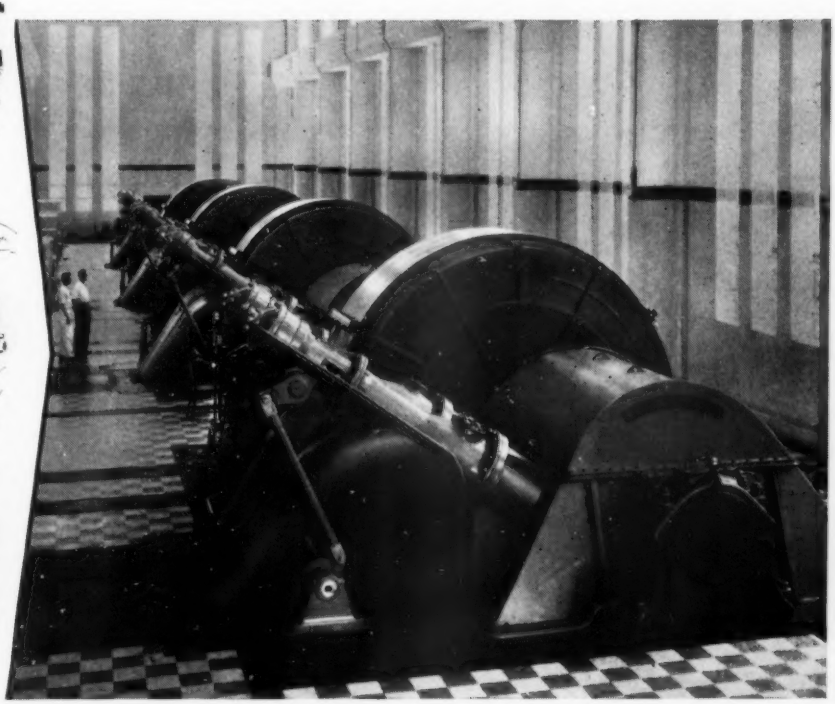
The outdoor 66,000 volt Switching Station at Sengulam.



Four 11,000/66,000 volt transformers at Sengulam.



The control desk and relay panel in Sengulam Power House.



The entire plant and equipment for the Sengulam Power Station in the Travancore-Cochin State, India, was supplied by The ENGLISH ELECTRIC Company. The equipment included four 36 in. dia. cylindrical-balanced high-pressure inlet valves; four 12 MW, 1,120 ft. head, 500 r.p.m. turbo-alternator sets; four 11/66 kV transformers; 66 kV and lower-voltage switchgear and control panels; and additional switchgear at the Pallivasal Switching Station.

This is typical of the comprehensive hydro-electric installations supplied by 'ENGLISH ELECTRIC' to many parts of the world. *Every aspect of hydro-electric design and manufacture is dealt with inside the Company's organisation.*

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hydro-electric equipment

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CONVERTIBLE SHOVEL
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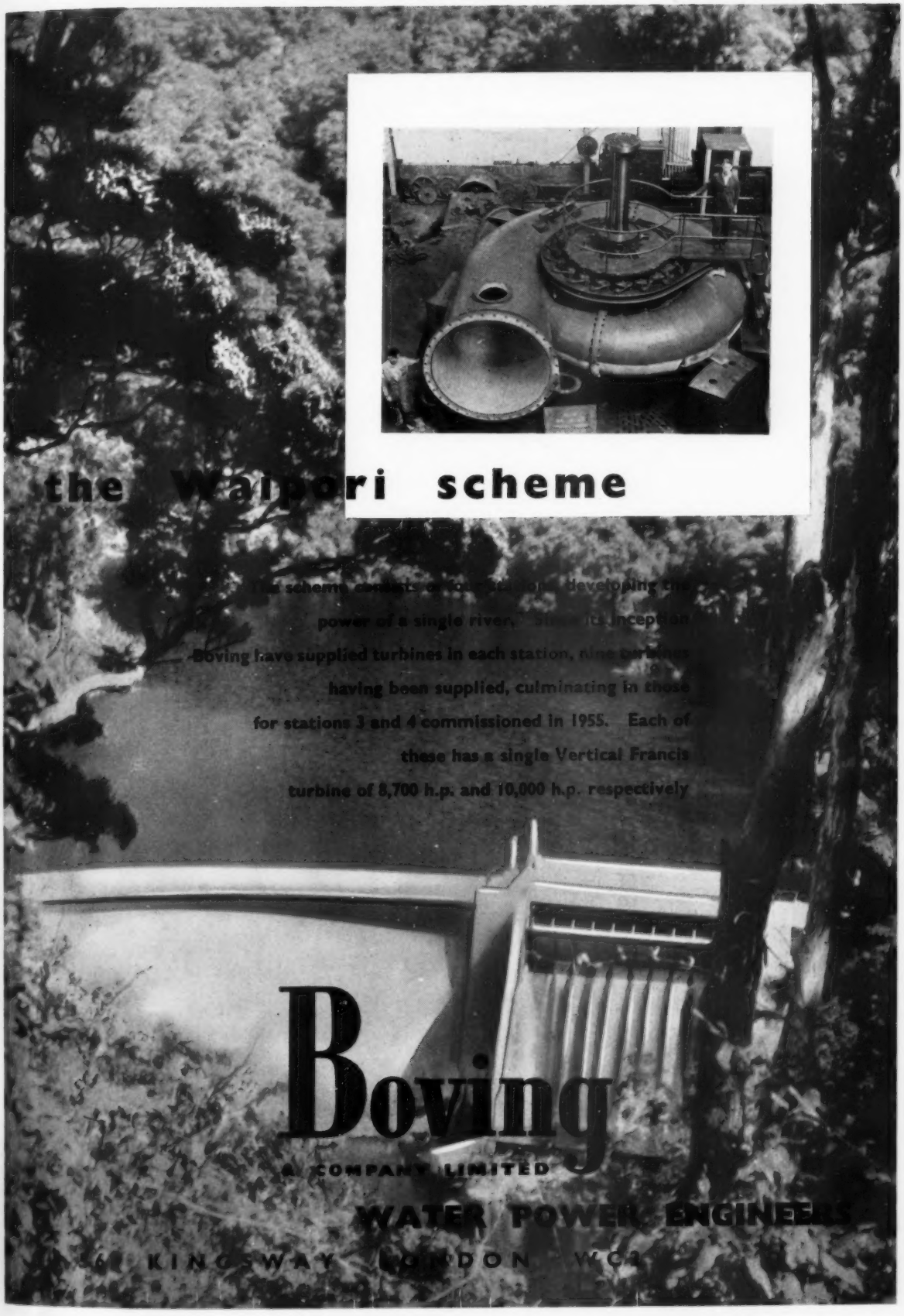
The Convertible Power Shovel featured by Hitachi, Ltd. has not only been in extensive use in Japan but also has been exported to many markets where full play in dam construction and other development work has been given to confirm its excellent qualities of solid construction, precise work, swift operation and ease in handling.

The versatility of this Hitachi Convertible Shovel is a most valuable characteristic as it can be used with a series of interchangeable front-end attachments, including Shovel, Drag Shovel, Dragline, Crawler type Crane with Hook, Crawler type Crane with Bucket and Skimmer, Pile Driver, etc.


the Waipori scheme
power of a single river.
having been supplied, culminating in those
for stations 3 and 4 commissioned in 1955. Each of
these has a single Vertical Francis
turbine of 8,700 h.p. and 10,000 h.p. respectively
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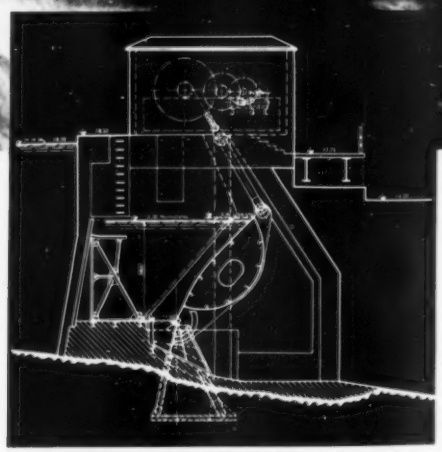
All hydraulic structures (including mechanical and electrical equipment) are supplied and erected ready for operation



Cross section through a weir with fish-belly flap

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longer life ...

You can't beat the Silver Three. It will out-drill and out-last any other machine of its weight and most heavier ones. And there are figures to prove it. It's designed specifically for use with the work-saving Airleg — and you won't find a better combination anywhere.

BORE:	3" (76 mm.)
STROKE:	1 15/16" (49 mm.)
WEIGHT DRY:	47 lb. (21 kg.)
WEIGHT WET:	49 lb. (22 kg.)

... the record-breaking

Silver Three

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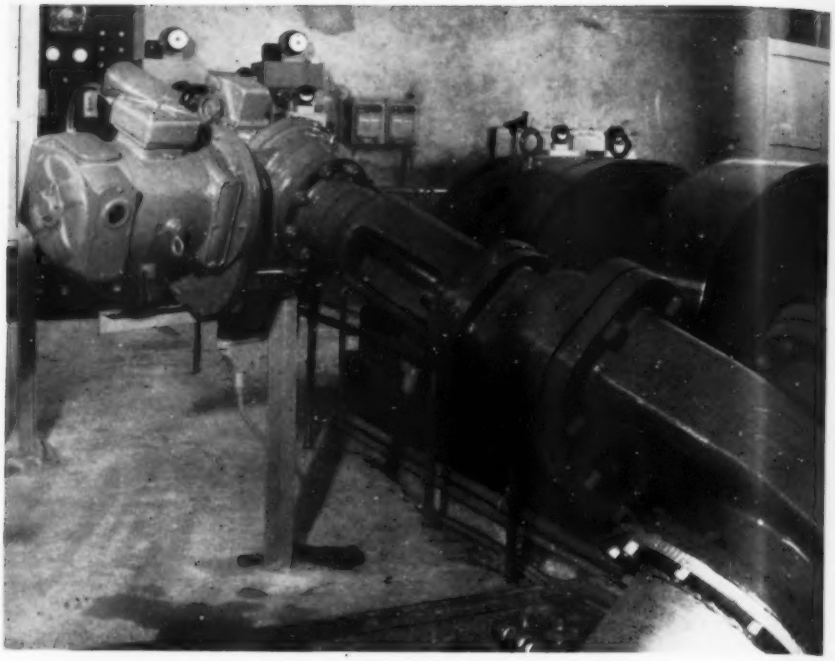
HH5

At the Power Station



SLUICE VALVES

The range of Glenfield Sluice Valves for turbine inlet control or isolating purposes covers round-bodied parallel faced valves for high head conditions, oval-bodied valves with wedge-shaped doors for medium and low pressures, and spectacle-eye valves for situations where the frictional head losses through a valve have to be at a minimum, or where the water may be gritty.

The illustrations show an 18 in. dia. electrically actuated oval-bodied valve of Meehanite cast iron for a head of 150 ft. in Assegaai Power Station, South Africa, and a similar 20 in. dia. hydraulically operated valve for a head of 372 ft. for Glen Lussa Hydro-Electric Scheme in Scotland.

Glenfield

GLENFIELD & KENNEDY, LIMITED, KILMARNOCK

Valve Specialists and Hydraulic Engineers for over a century

SIEMENS

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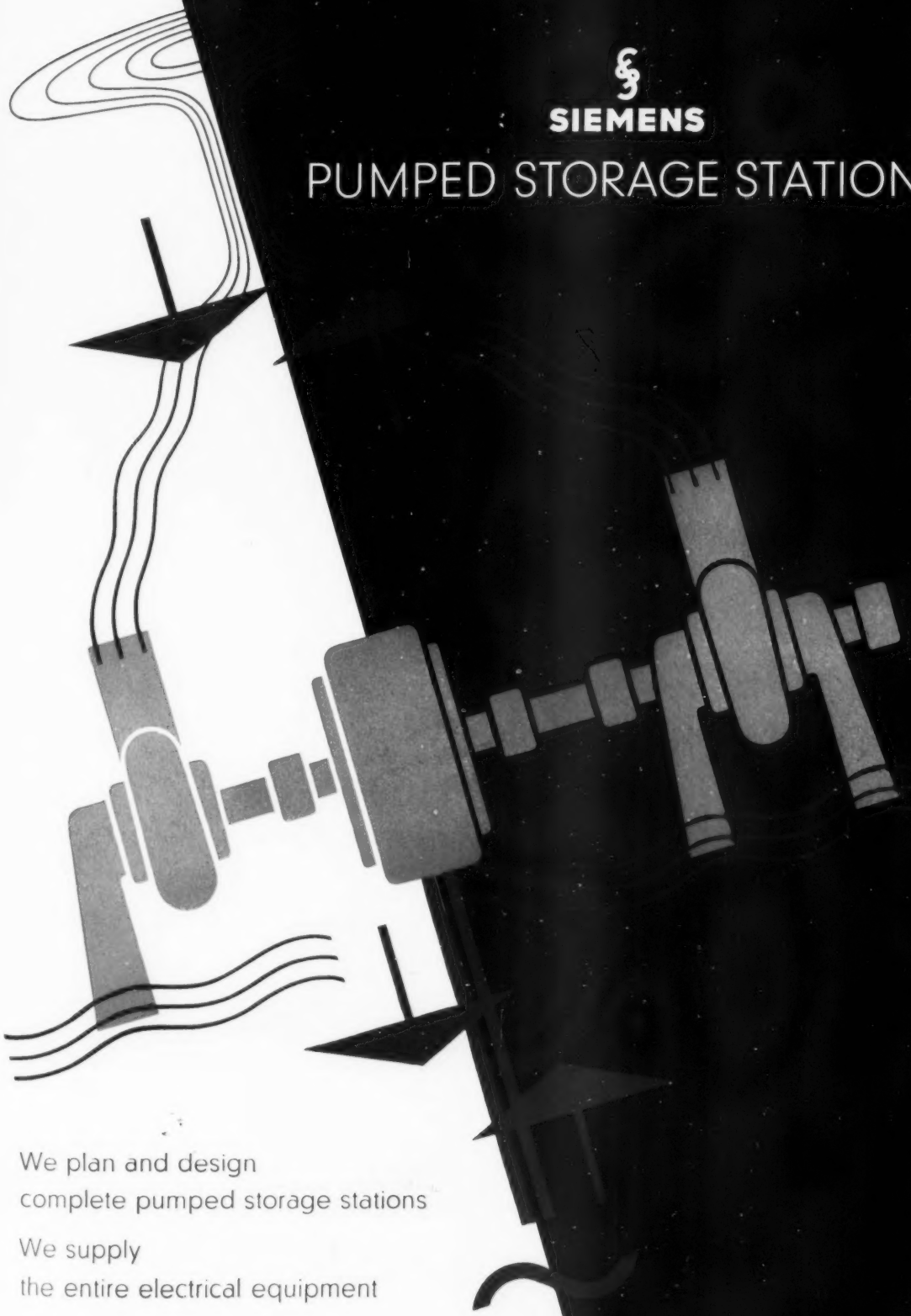

We plan and design
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We supply
the entire electrical equipment

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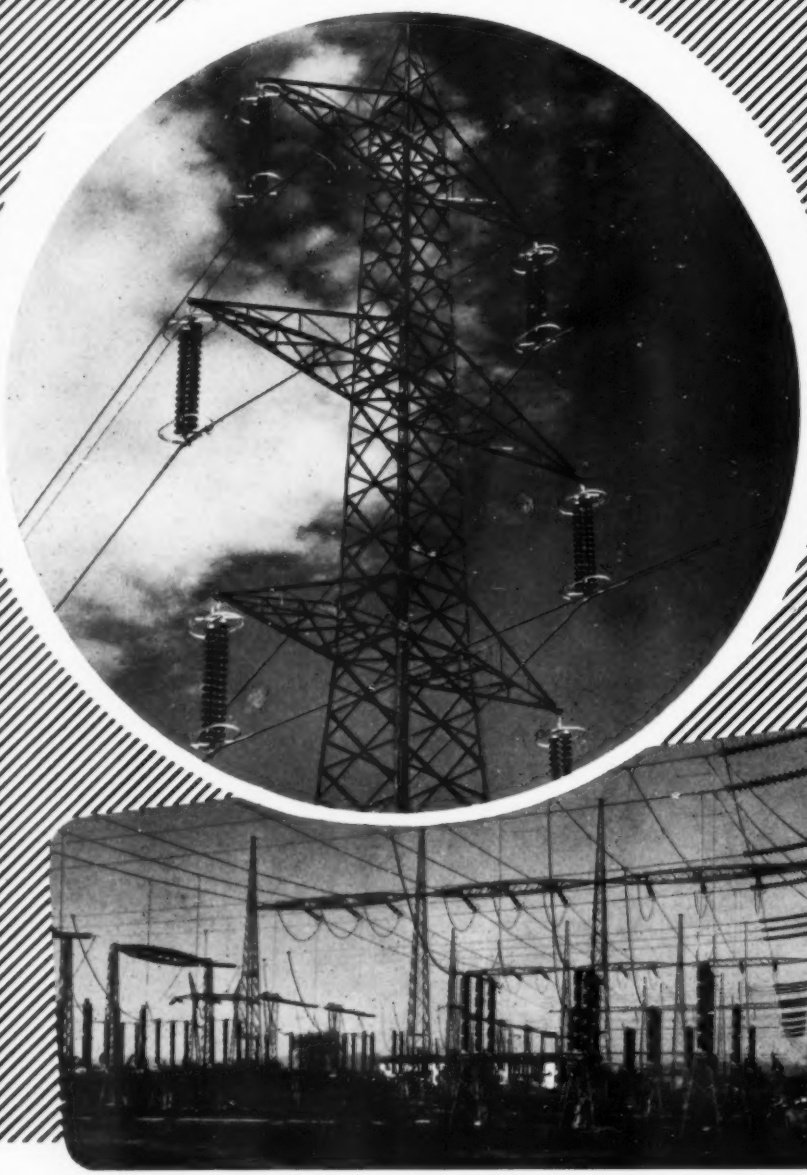
SALVI



3-230 kV Villa Valle-Conegliano 4 Twin S.C.A. Conductor Transmission Line (Societa TERNI-Rome)

For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialized in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints.
The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including voltages of 220/380 KV, and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

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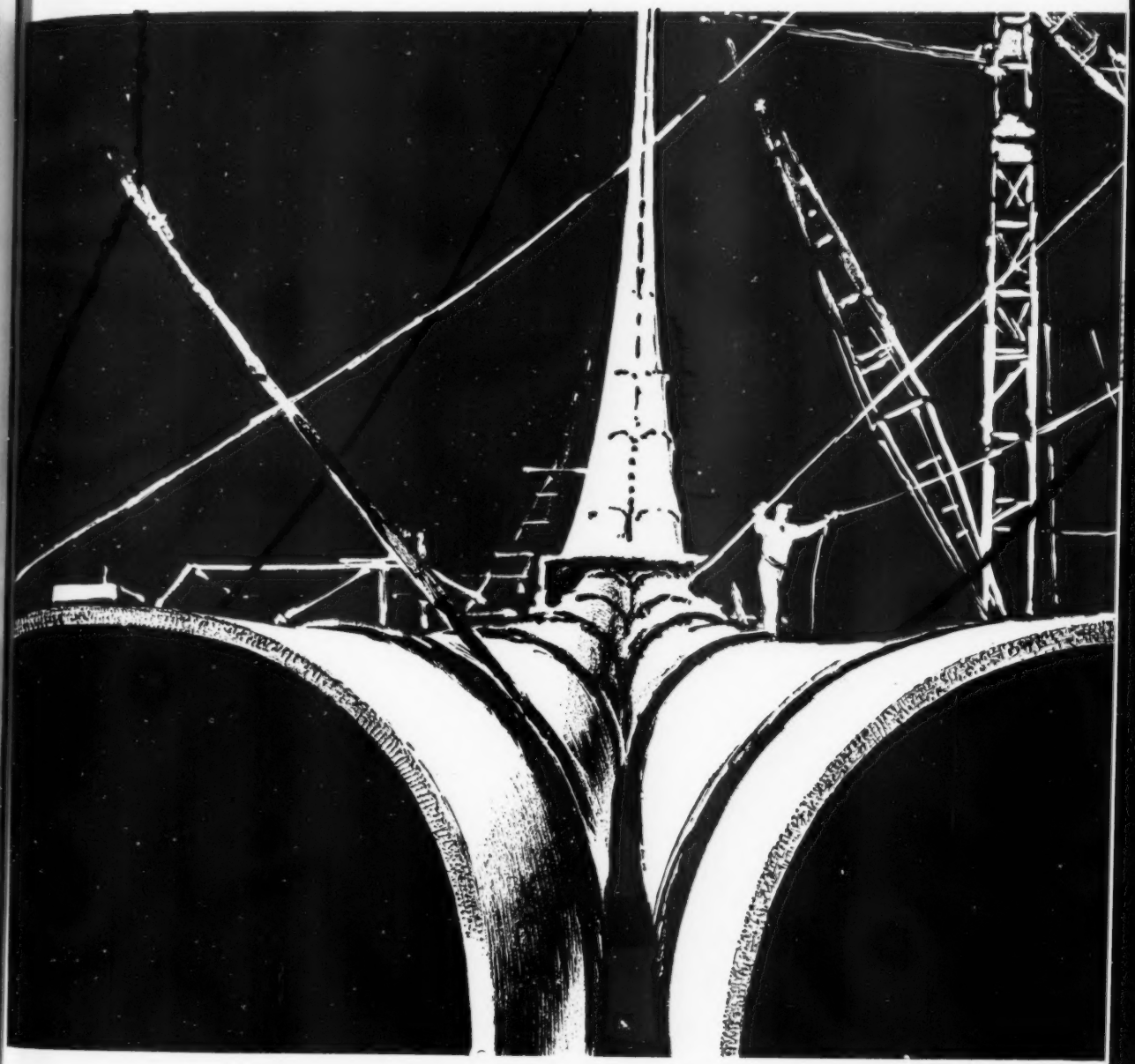

6/242/1

More strength...

A tame cataract, like a tame horse, has more strength than its wild brother. Mannesmann — the world's first seamless steel tube maker — coaxes waterfalls into penstocks that may drop as much as 6 000 feet to great power plants whose turbines race the lightning, sending millions of tame horses to do the world's work. Penstocks designed, supplied, and built by Mannesmann defy pressures up to 3 000 lbs. per square inch.

MANNESMANN-EXPORT GMBH DÜSSELDORF

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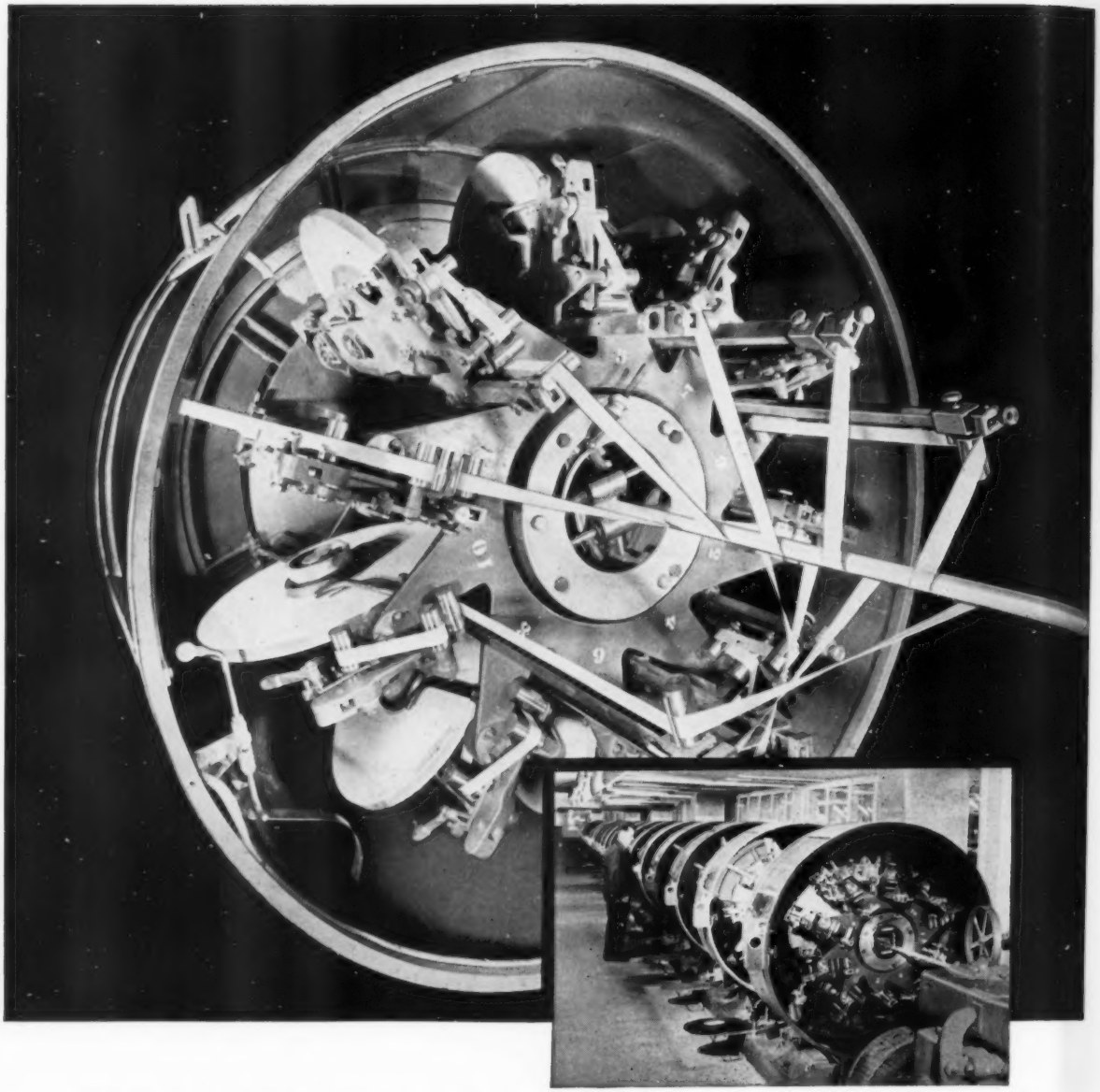

More than a lap ahead

This specially designed paper-lapping machine, the first of its kind in the country, is housed in an air-conditioned enclosure.

With 20 reversible lapping heads, each capable of applying 10 papers, up to 200 layers of insulation can be applied simultaneously at controlled tensions.

Precision lapping in a controlled atmosphere is now our standard practice for all super-tension cables — a further guarantee of the reliability of Pirelli-General Cables supplied for the highest voltages.

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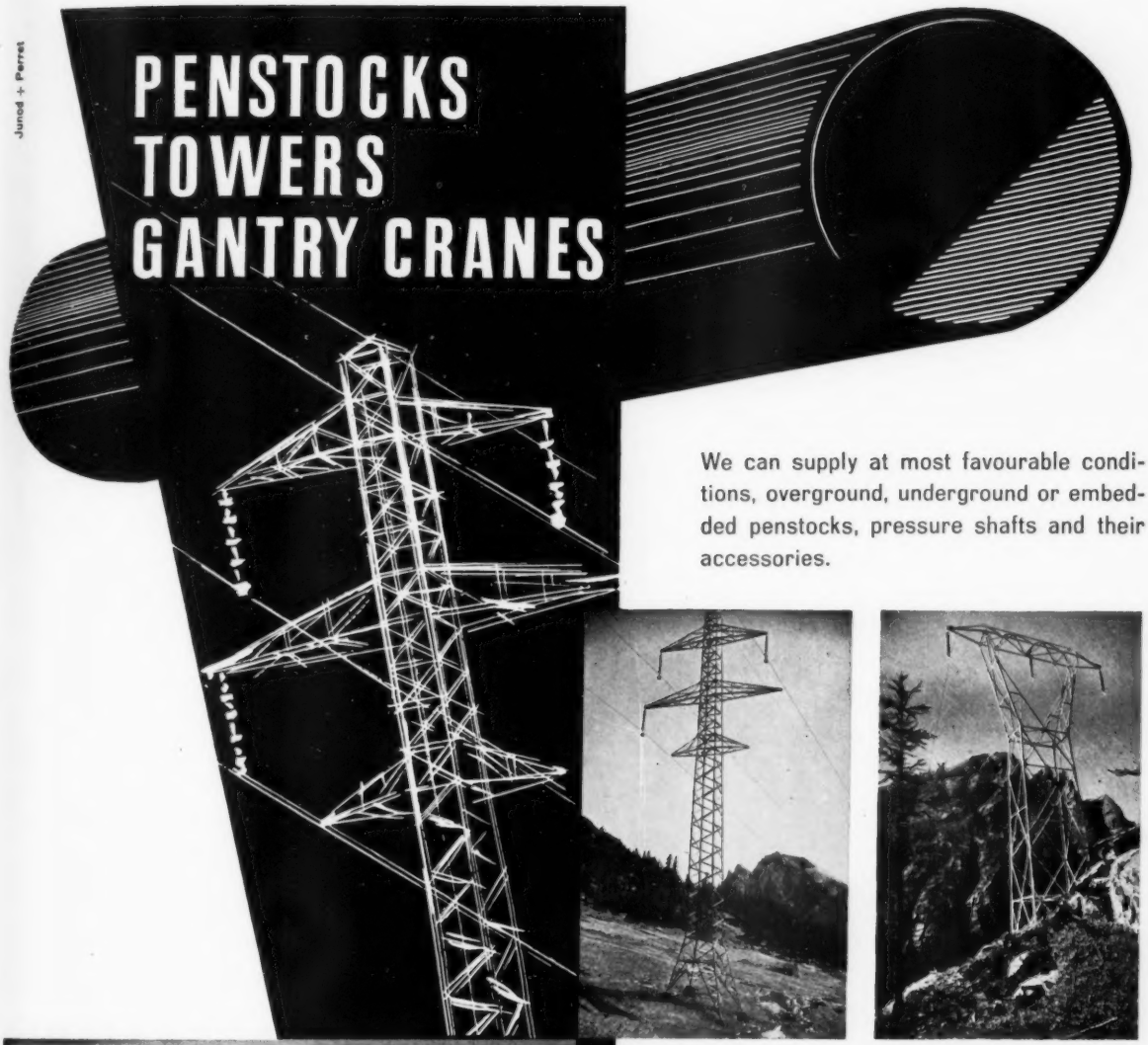
ASSOCIATED COMPANY OF THE GENERAL ELECTRIC CO. LTD.

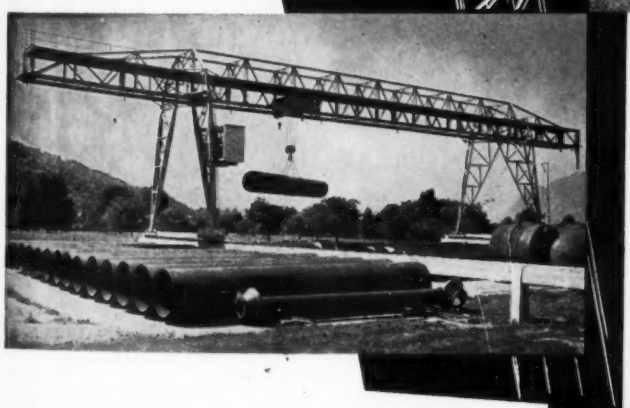
Junod + Perret

PENSTOCKS
TOWERS
GANTRY CRANES



We can supply at most favourable conditions, overground, underground or embedded penstocks, pressure shafts and their accessories.

Towers for electric transmission lines, for teleferics or radio aerials.
Steel structures for buildings.
Reservoirs of any shape and dimensions.



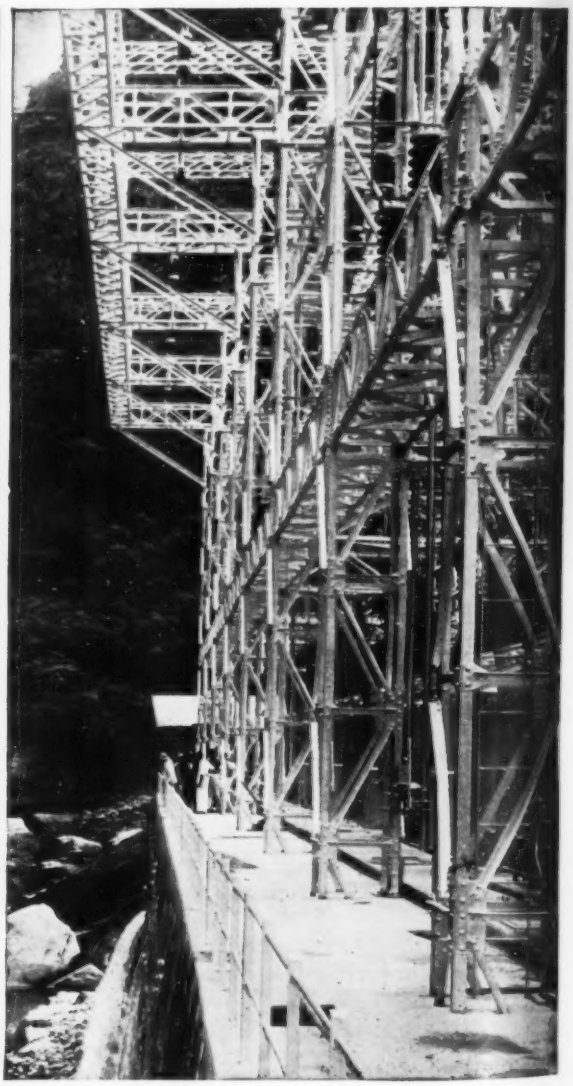
Gantry crane, lifting capacity 3 to 25 tons, distance between rails 36 m., 2 overhangs of 12 m., total length 60 m.

giovanola

GIOVANOLA FRÈRES S. A., MONTHEY (VS) SUISSE

S.P.P. Post Insulators were used on all the 110kv outdoor switchgear on the Jog Falls Hydro-electric Scheme

The outdoor switchgear at Jog Falls Power Station, in Mysore State, India, equipped with S.P.P. Cylindrical Post Insulators type P.701.



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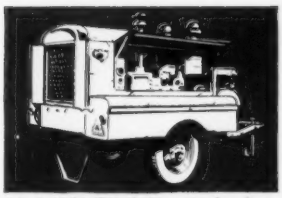
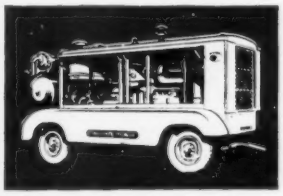
S.73

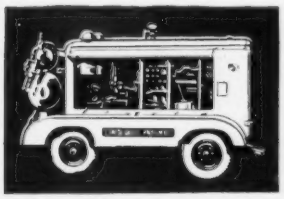
For the construction of new licensed premises at Peckham the Contractors, Holliday & Greenwood Ltd., use the new CP Power-Vane rotary compressor.



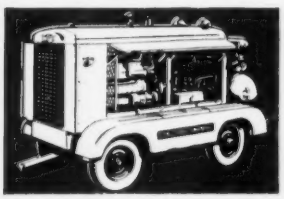
Model 125-RO-2 shown in the photograph will operate two medium breakers or rock drills.



Model 600-RO-2 powered by Rolls-Royce oil engine is an ideal unit for big construction schemes.



Model 365-RO-2 powered by Rolls-Royce, is a plant of ample margin for average construction needs.



Model 210-RO-2 is a medium capacity plant suitable for 'four-tool' operation.

This compressor slashes maintenance and repair costs

Incorporating the most important design advances since portable air compressors came into general use, Power-Vane rotary compressors eliminate clutch, crankshaft, valves and pistons, and are fast becoming the first choice of Contractors on every type of job. Maintenance and repair time is virtually eliminated. The entire unit runs in oil and is oil cooled. Fully automatic safety devices prevent damage by oil pressure failure or excessive temperature. Available in a wide range of types for different applications, the Power-Vane Compressor is something every Plant Engineer should know about. Ask for Catalogue 58c.

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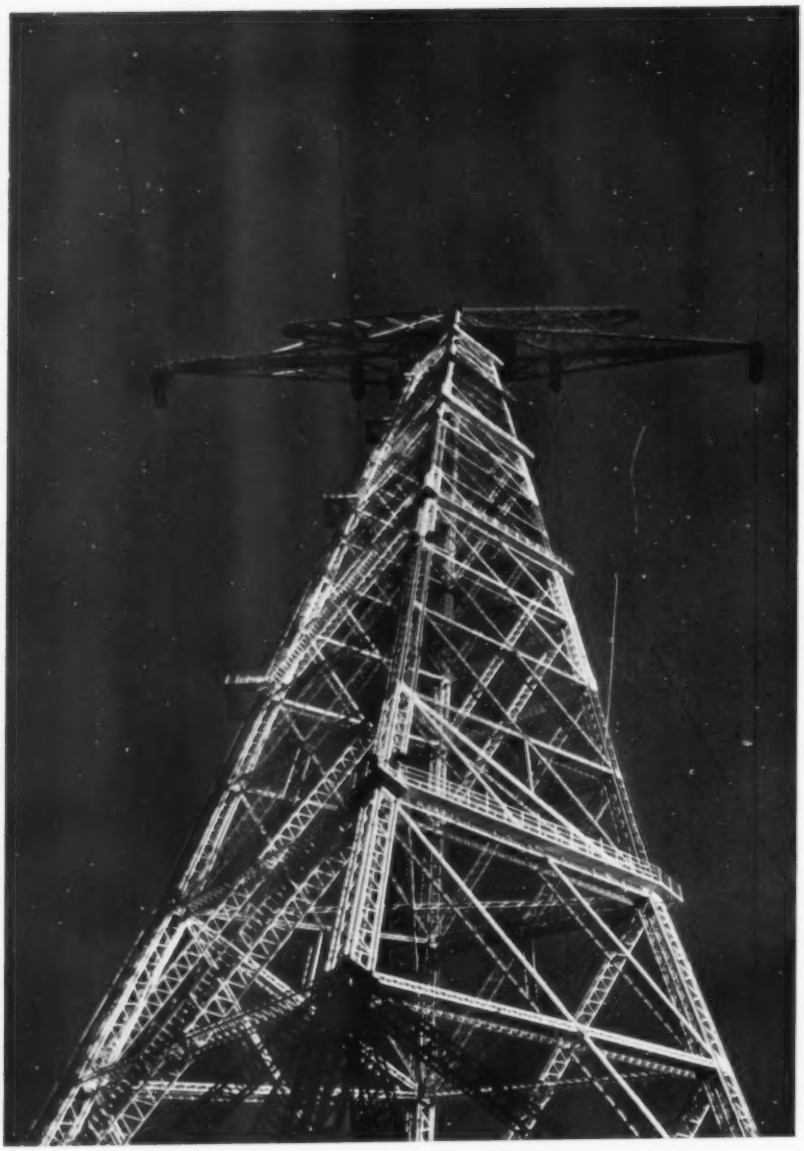

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Arpic Engineering, one of the world's foremost manufacturers of portable compressors, is now part of the Atlas Copco Group. Previously, both companies manufactured an extensive range of portables. The new *combined* range is therefore one of the most comprehensive in the world. From one source you can now choose portable compressors with air deliveries ranging from 36 to 600 cubic feet per minute. Portables for any operation, climate or altitude—*all* from Atlas Copco.

The various plants of Atlas Copco and Arpic will now come under a common direction and a combined team of production engineers. This dovetailing of facilities will result in increased production and earlier delivery dates for the new range. It will also speed servicing and the supply of spare parts. Other benefits will emerge from the pooling of technical knowledge, leading to positive improvements in design. The new range, besides being a thoroughly comprehensive one, promises to be one of the most advanced and most reliable on the market.

Atlas Copco is the largest group of companies in the world specialising solely in the development and manufacture of compressed air equipment. With the addition of some 30 Arpic overseas depots, there will now be Atlas Copco companies or agents selling and servicing the new range in ninety countries all over the world. Please write for further details of the new range and its distribution to your local Atlas Copco company or agent, or to Atlas Copco AB, Stockholm 1, Sweden.

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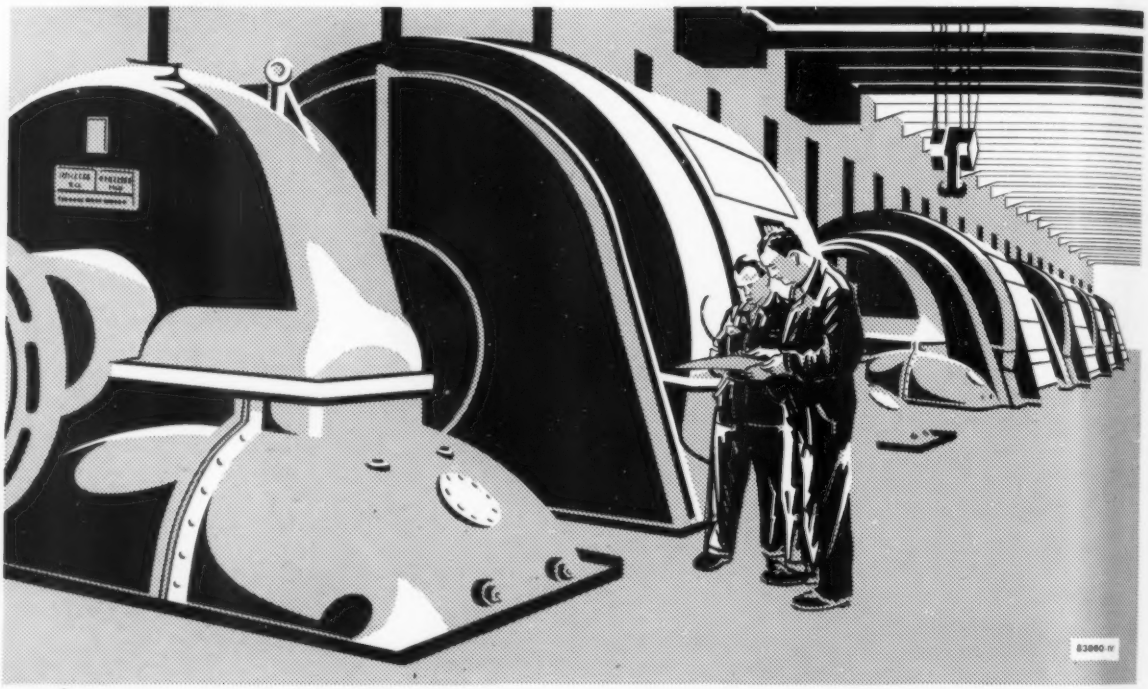
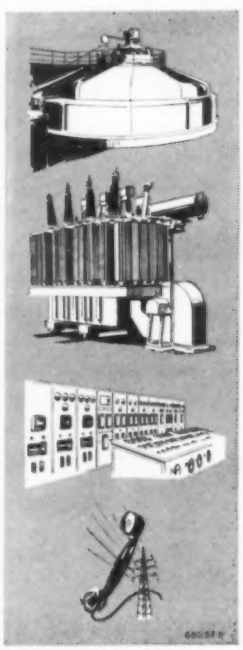
for high- and low-head hydro-electric stations



Switzerland's largest hydro-electric plant, the Riddes station owned by the Forces Motrices de Mauvoisin, is equipped with five Brown Boveri alternators aggregating 335 MVA.



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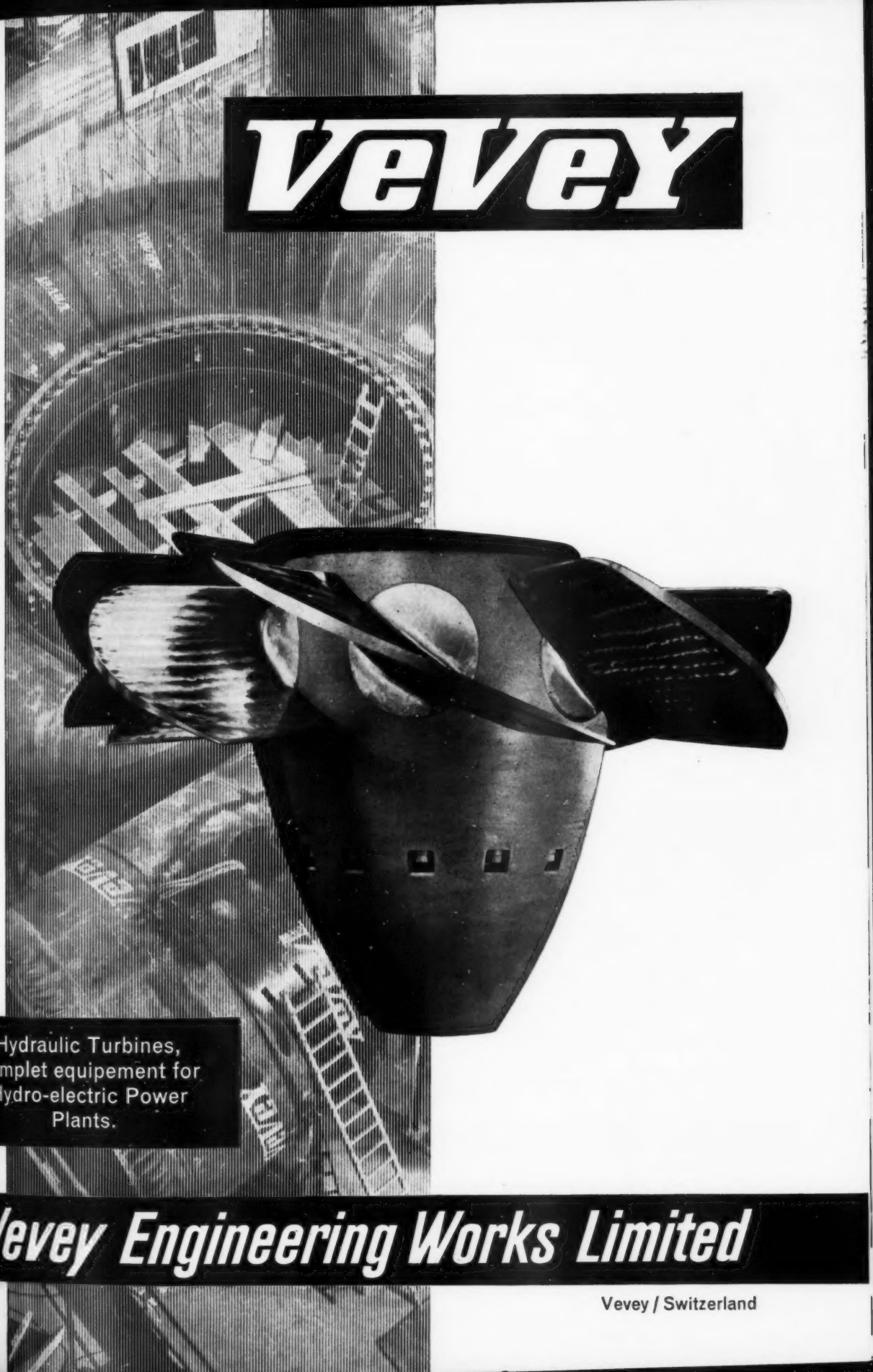
Representatives in most countries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Output **63,000 H.P.,** speed 750 r.p.m., max. head **455 m.**

Similar high-pressure Francis turbines are in course of manufacture for the Safienplatz Power Station of Messrs. Zervreila A.G. (Switzerland)
Output 60,000 H.P., speed 750 r.p.m., max. head 422 m.

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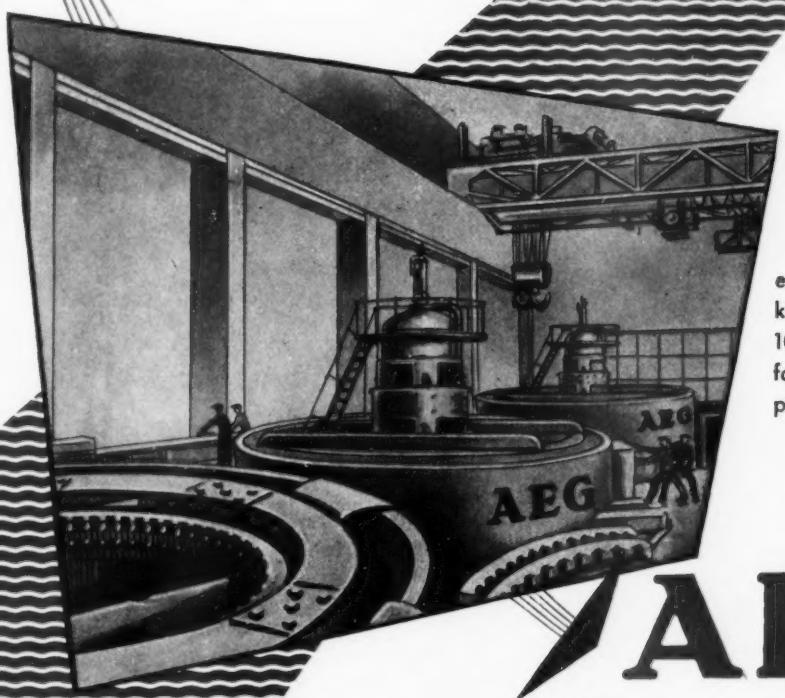
Sixty years

accumulated-experience supplies power-even at the polar circle



3 AEG generators, each rated at 30000 kVA, 136 rev/min., 10500 V, 50 c/s, built for a hydro-electric power station in the north of Finland.

6970e

AEG

AEG means ELECTRICITY

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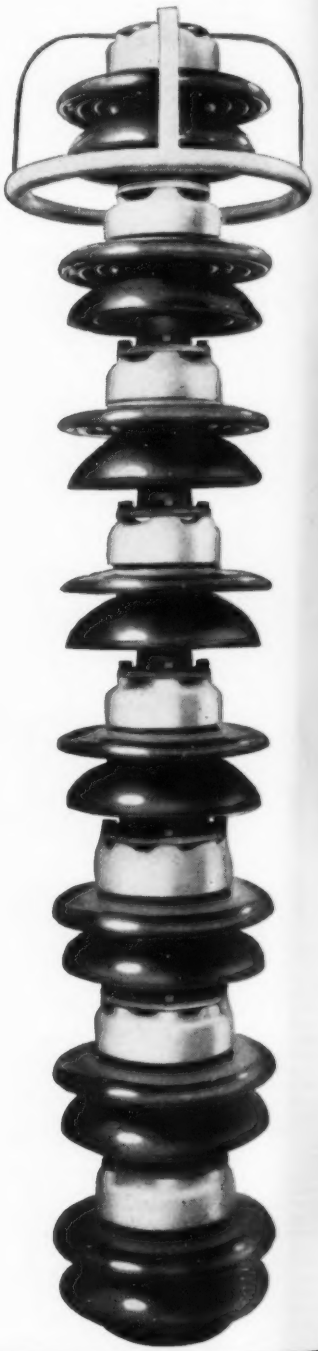
POST INSULATORS

FOR 275 K.V. SWITCHGEAR



This post insulator was designed and manufactured by Bullers Limited to the requirements of the British Electricity Authorities specification for 275 K.V. Switchgear.

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Height of post 116"
Cantilever strength 2,000 lb.
Dry withstand test 580 K.V.
Wet withstand test 520 K.V.

COMPLETE

hydraulic equipment

FOR WATER POWER PLANT

View in erection shop, showing assembly of large Francis Turbines. In the background, the giant turning mill.

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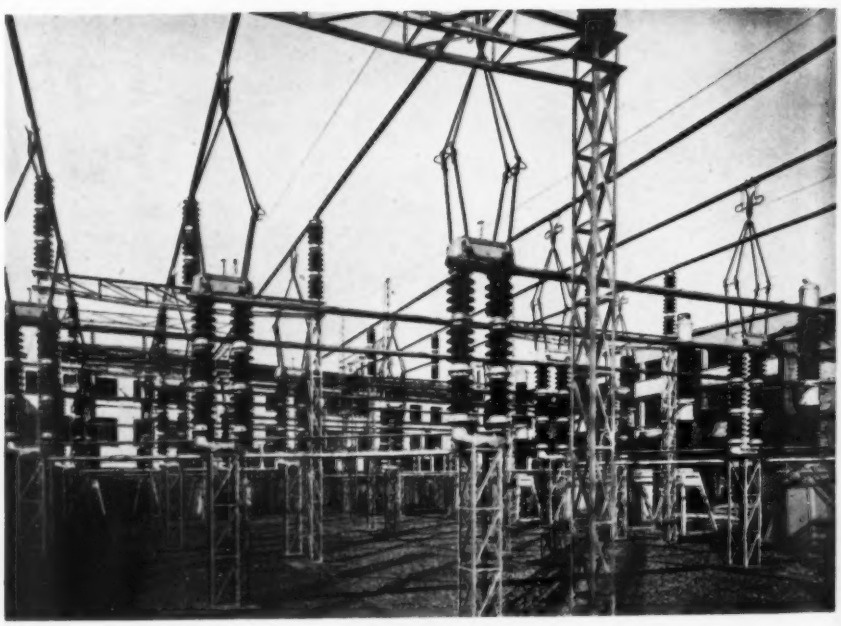
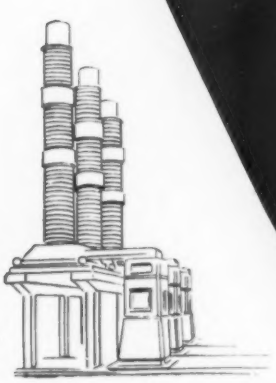


150 kV 600 Amps pantograph isolators installed at an Italian plant.



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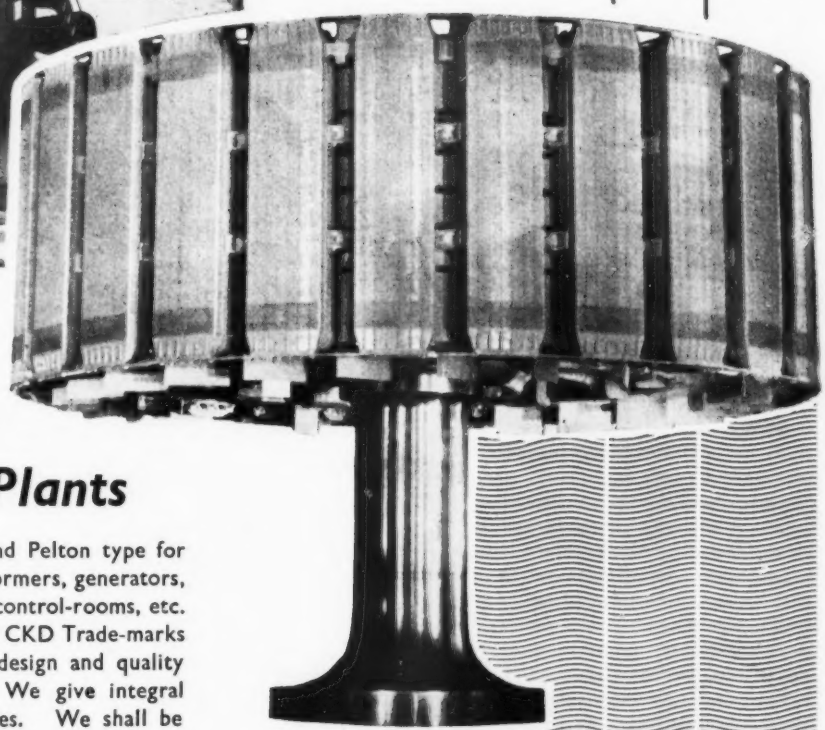

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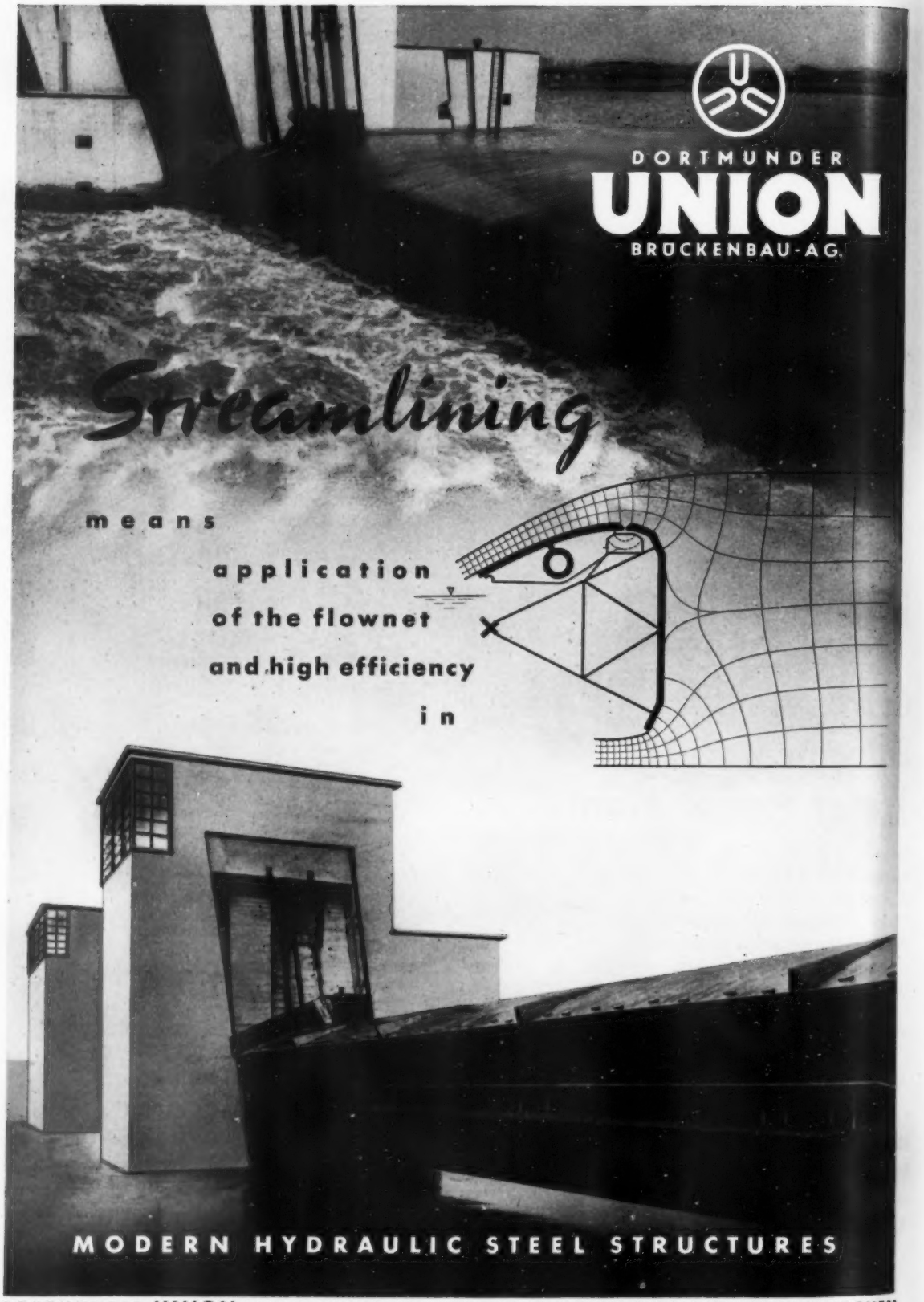

DORTMUNDER UNION BRUCKENBAU-AG · PLANT AT DORTMUND AND GELSENKIRCHEN
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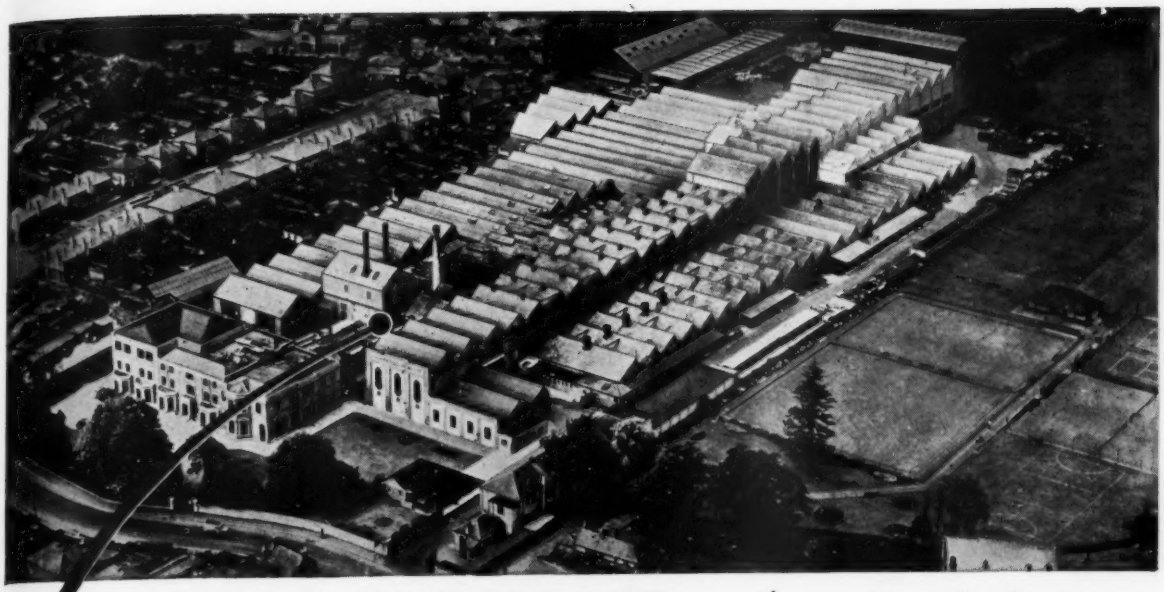

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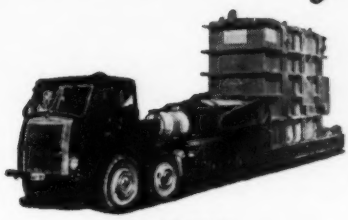

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Five 30 MVA 132/33 kV 3-phase Hackbridge transformers for the Electricity Commission of New South Wales.

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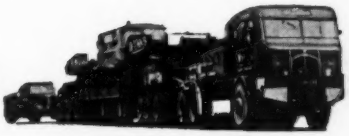
Four 20 MVA 100/6.6 kV 3-phase Hackbridge transformers for the Tata Hydro Electric Power Supply Co. Ltd.

HONG KONG

Three 5 MVA 33-22/6.6 kV 3-phase Hackbridge transformers. Photo by courtesy of the China Light and Power Co. Ltd.



ENGLAND

Six 70 MVA 11/134 kV 3-phase Hackbridge transformers for Skelton Grange Power Station, Leeds

CANADA

Two 60 MVA 125/66 kV Hackbridge transformers for Shawinigan Falls Power Station, Quebec.

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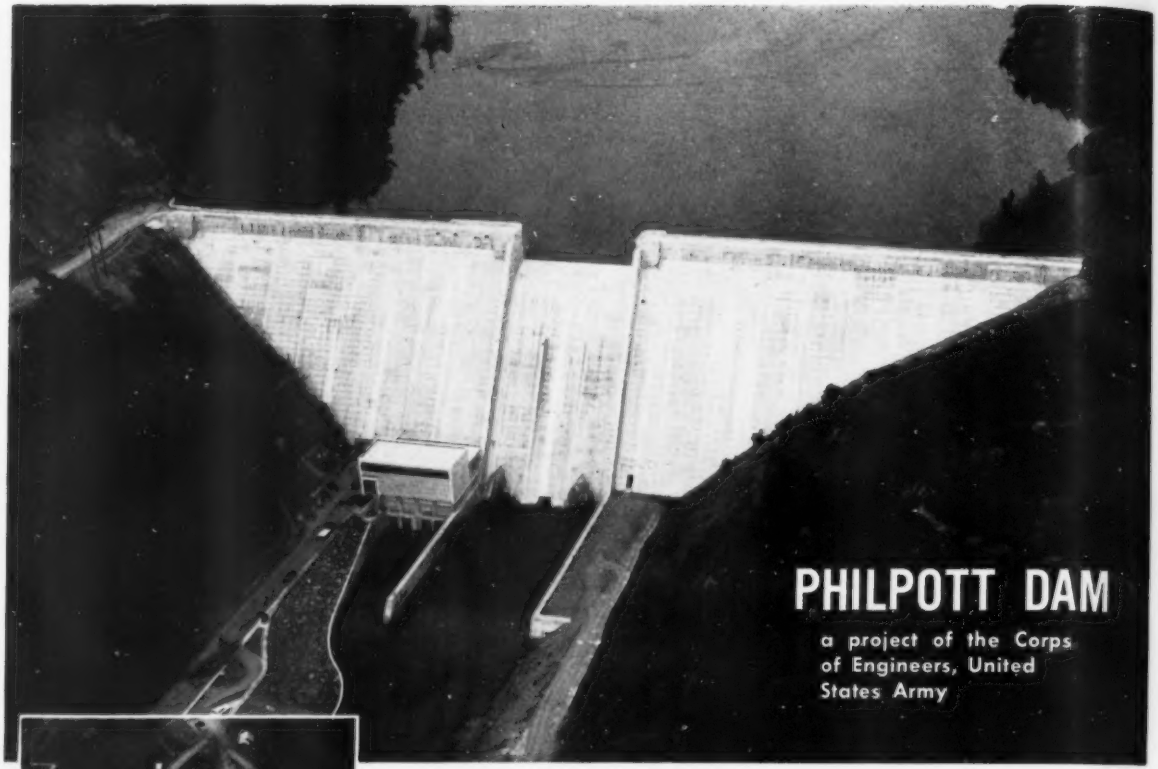

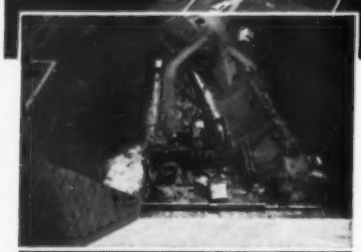

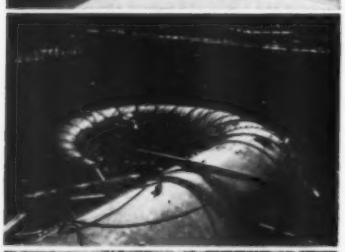

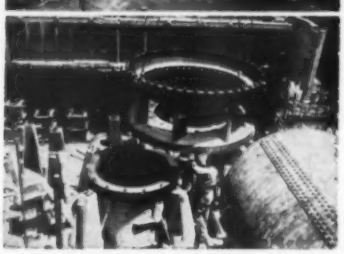

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Three Leffel turbines were installed at the Philpott power plant. Two are each rated at 9,400 h.p. under 152 ft. net head, at a speed of 227 r.p.m.; and the third is rated 860 h.p. at 720 r.p.m.

The view above shows the completed project. The views at the left show the project under construction, the spiral casing for one turbine in place, and a stay ring being lowered into place over the draft tube.

Other Leffel installations are dependably and efficiently producing power from water in this country and in all parts of the world. Leffel engineers are waiting to put their 94 years of experience with water power to work for you, whether your project is a completely new installation, or an expansion or rehabilitation of existing facilities.

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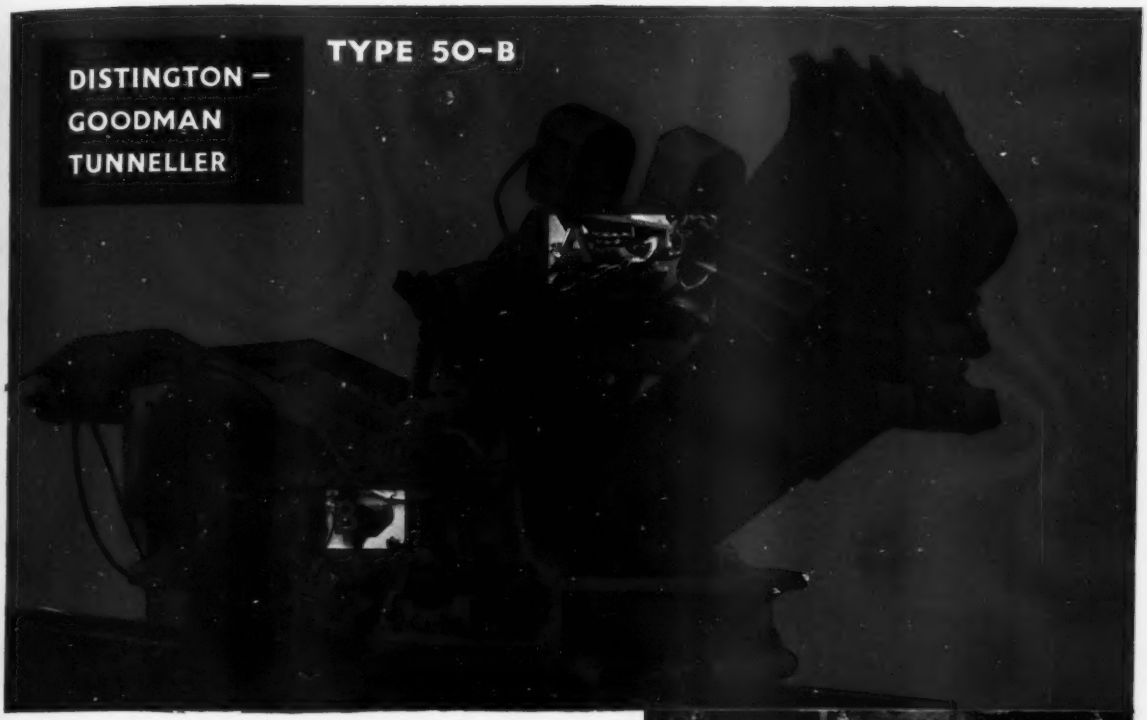

This machine driven by a 70 h.p. flameproof motor, has all its movements (forward and reverse tramming, and hoisting and swinging the boom and shovel) controlled by two hand levers and two foot pedals. Each pedal and lever operates an easily adjusted brake band on a planetary gear drum. There is adequate mechanical and electrical protection against overload.

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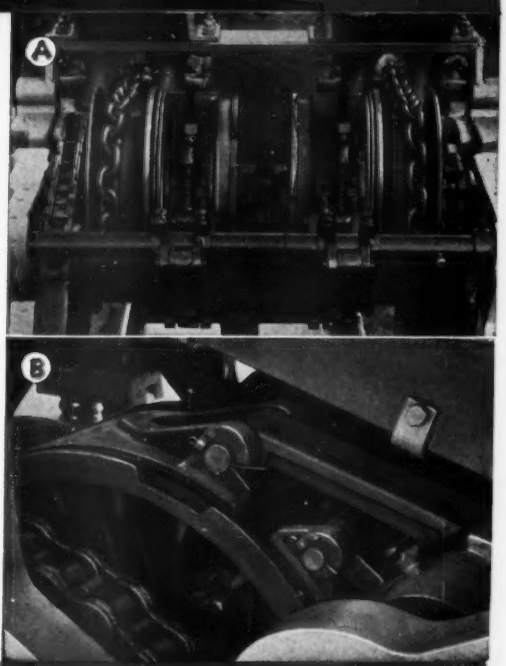
70 h.p. motor (AC or DC). Dipper capacity—13 cu. ft.
6 loading cycles per min. Loading capacity—81 cu. ft. per min.
Tramming speed—176 f.p m. forward, 120 f.p.m. reverse

BOOM LENGTH	CLEAN-UP AT TRACK LEVEL	OPERATING HEIGHT
5′	13′	8′ 8″
6′	14′ 6″	9′ 8″



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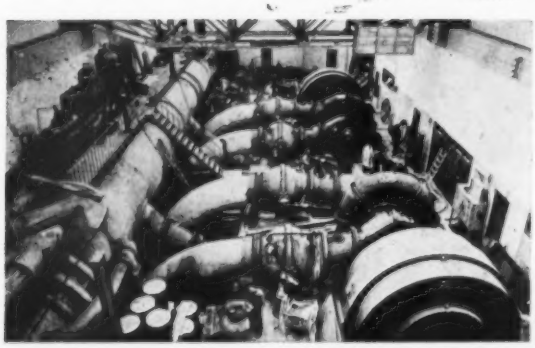
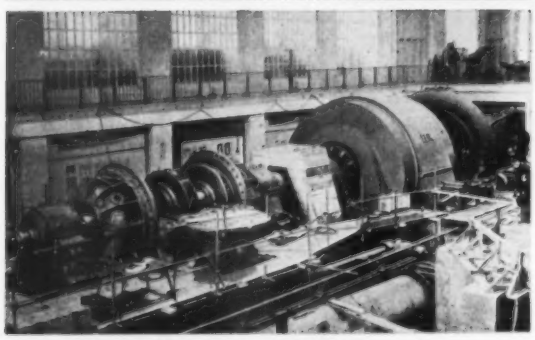
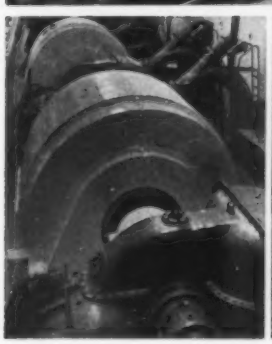
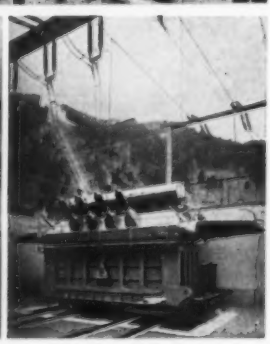


Moell Pumping Station at Mooserboden Reservoir: Two three-phase, squirrel-cage motors, direct-on-the-line start, each 9,100 h.p. at 494 r.p.m.

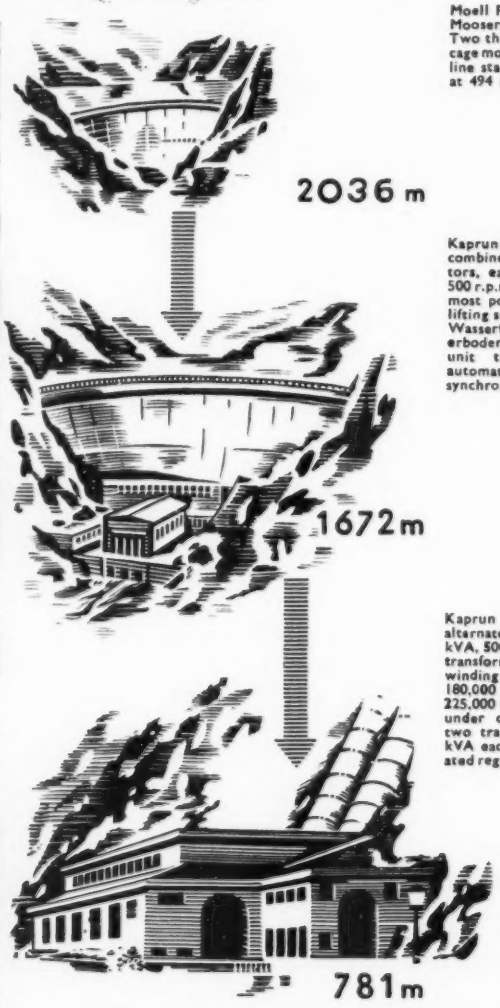


Kaprun Upper Stage: Two combined motor/alternators, each 62,000 kVA at 500 r.p.m. driving Europe's most powerful pumps for lifting storage water from Wasserfallboden to Mooserboden; also the related unit transformers, and automatic control of the synchronous machines.





Kaprun Main Stage: Two alternators, each 70,000 kVA, 500 r.p.m., with unit transformers; one three-winding transformer 180,000 kVA, rated at 225,000 kVA (a second one under construction), and two transformers 100,000 kVA each, all with associated regulating equipment.



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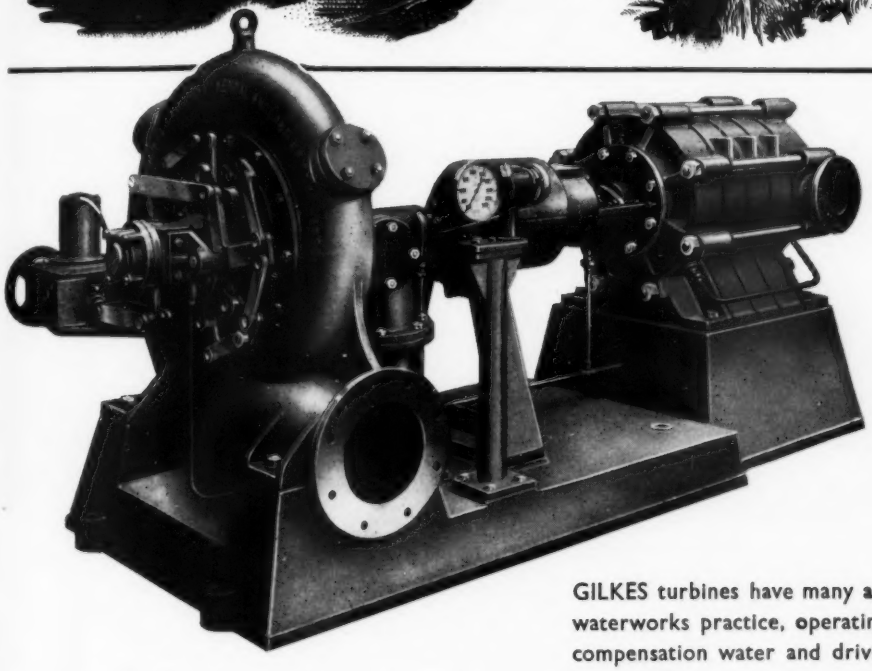

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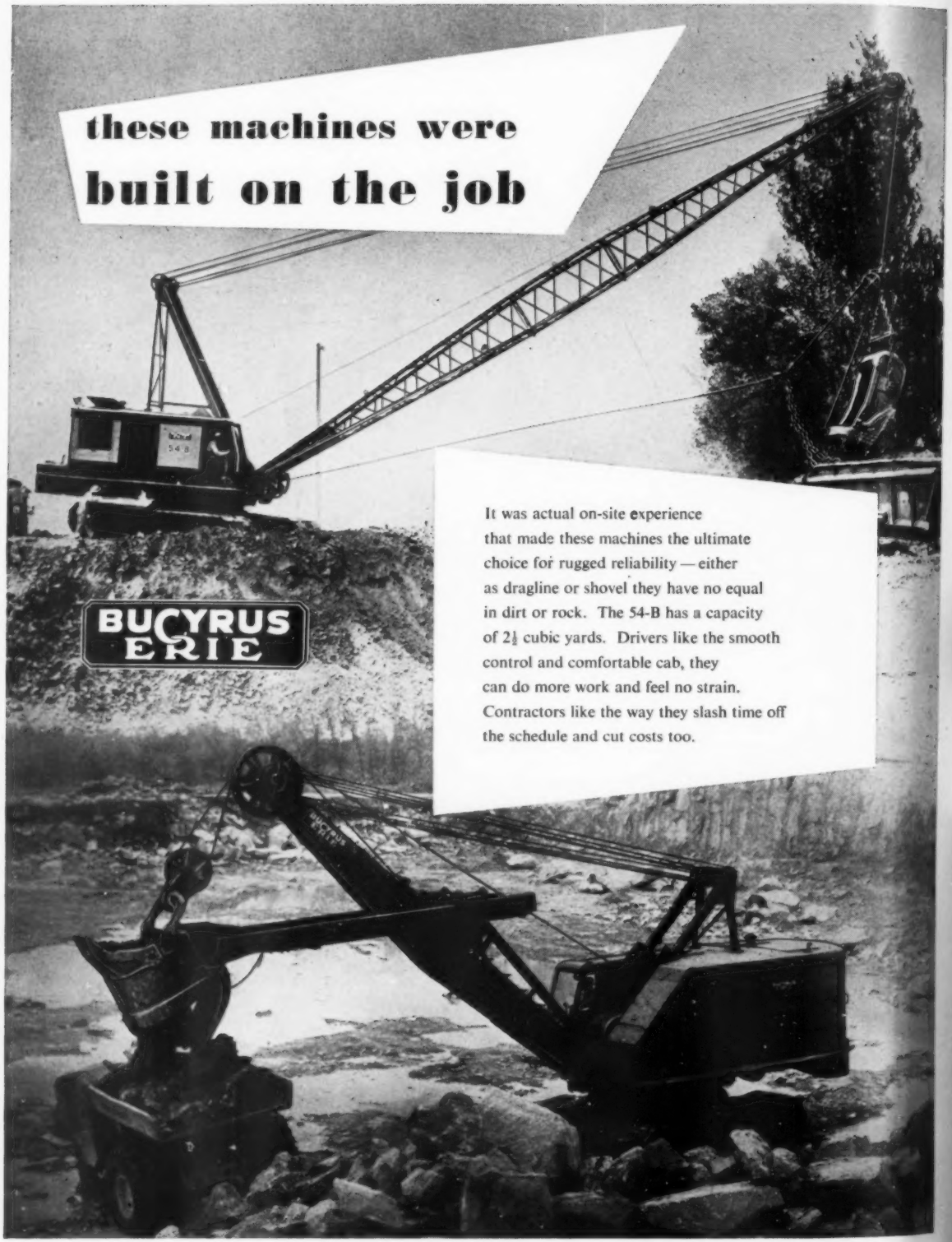
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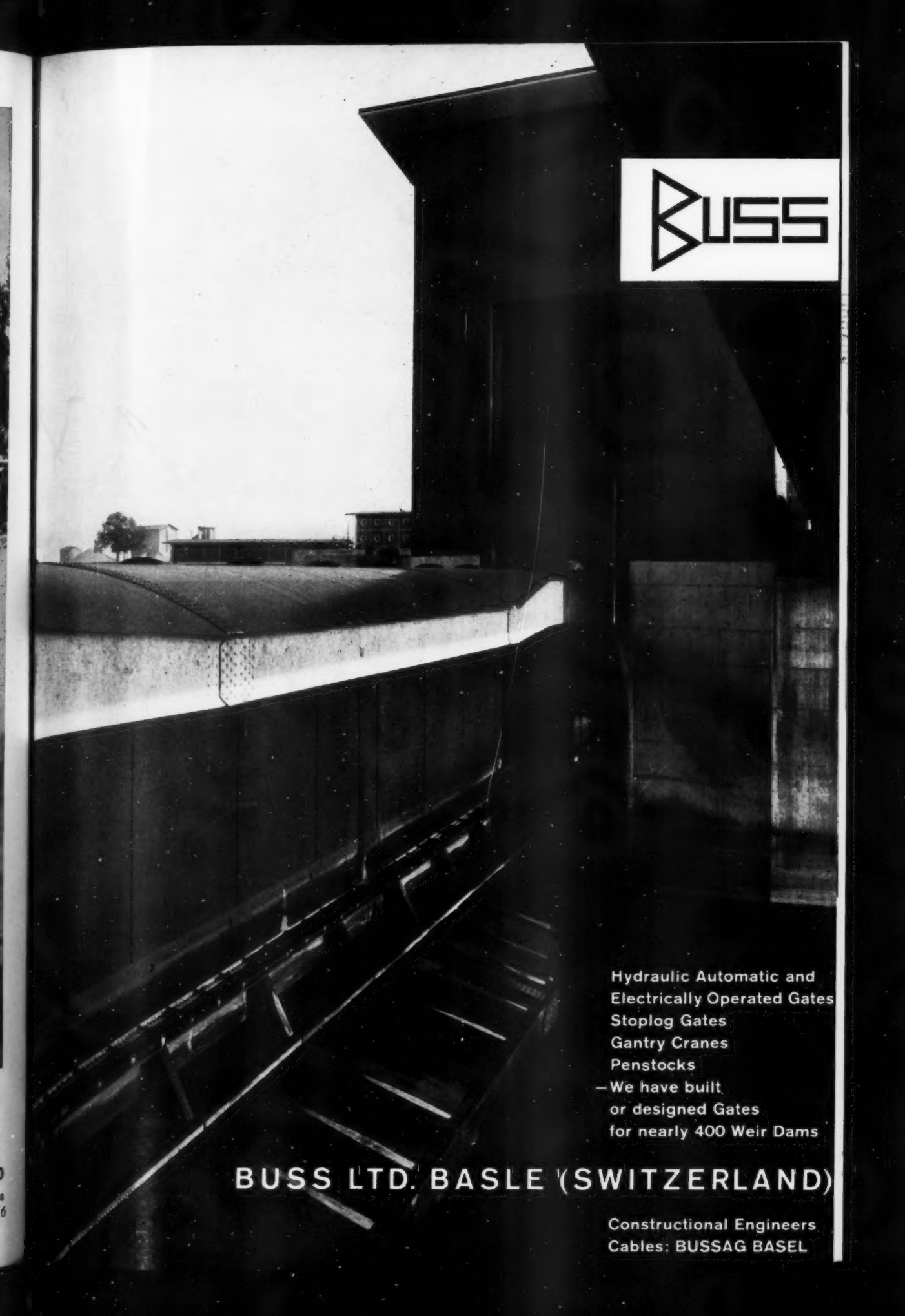
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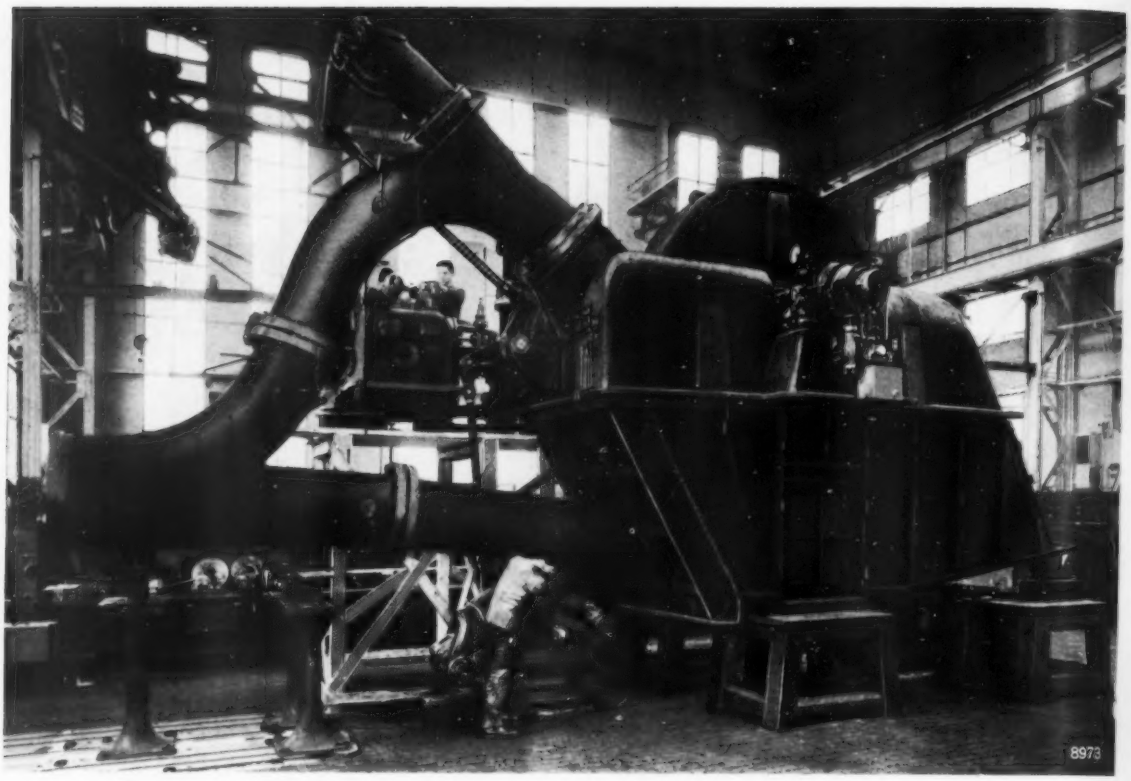

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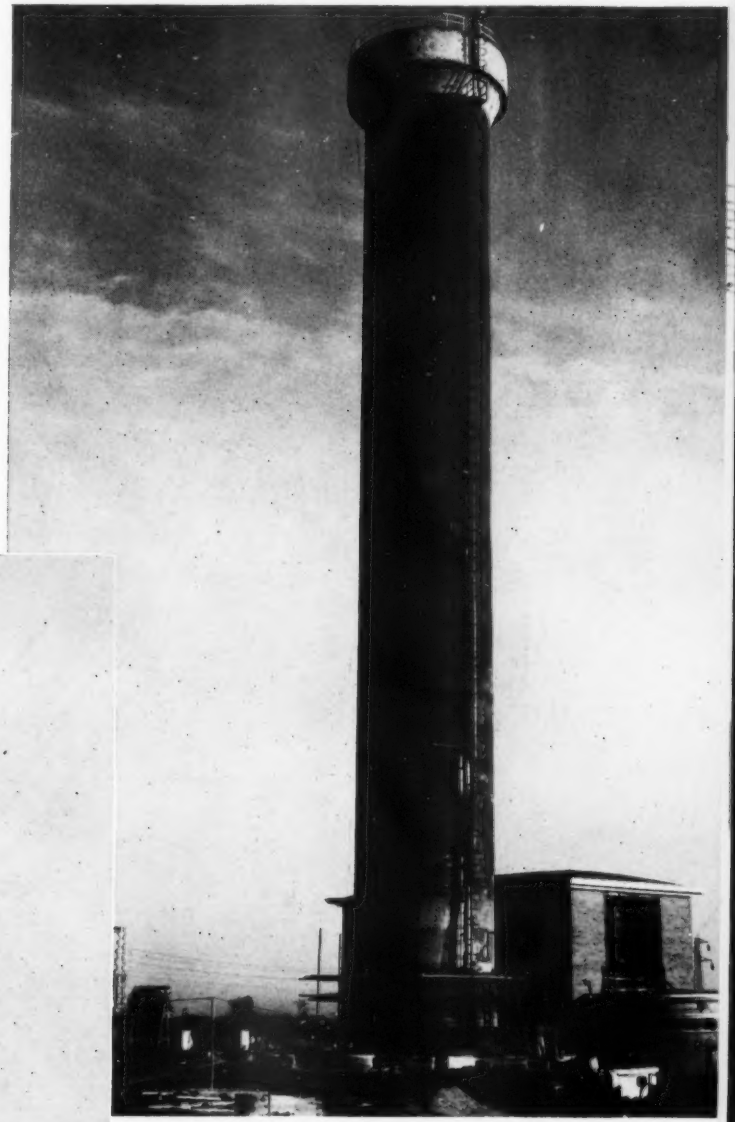

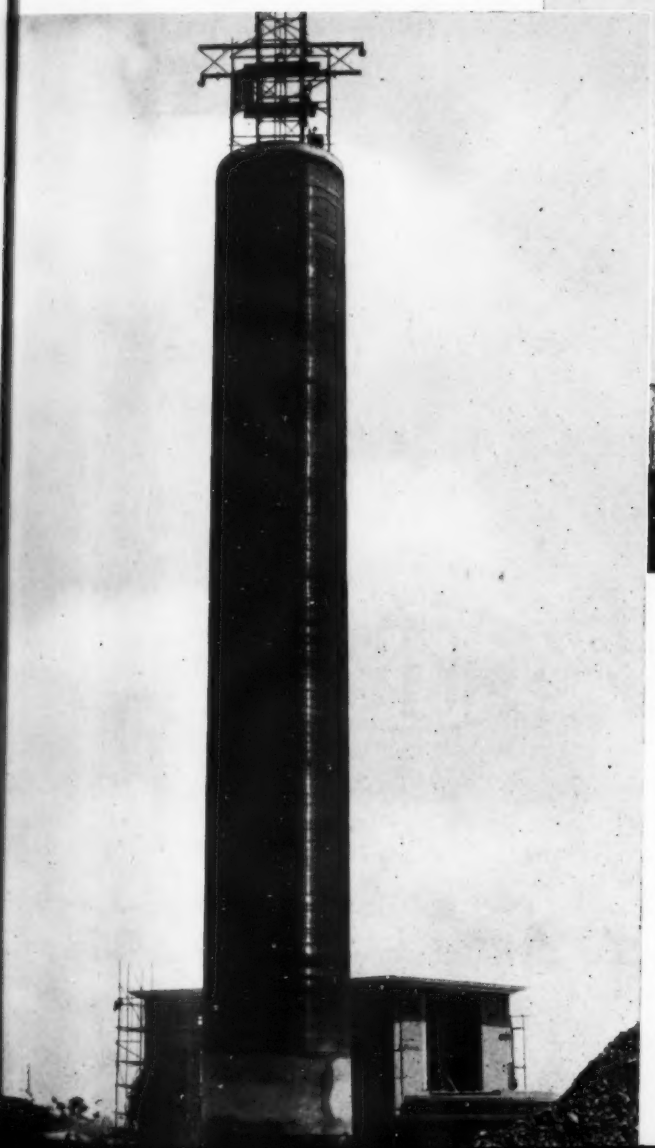

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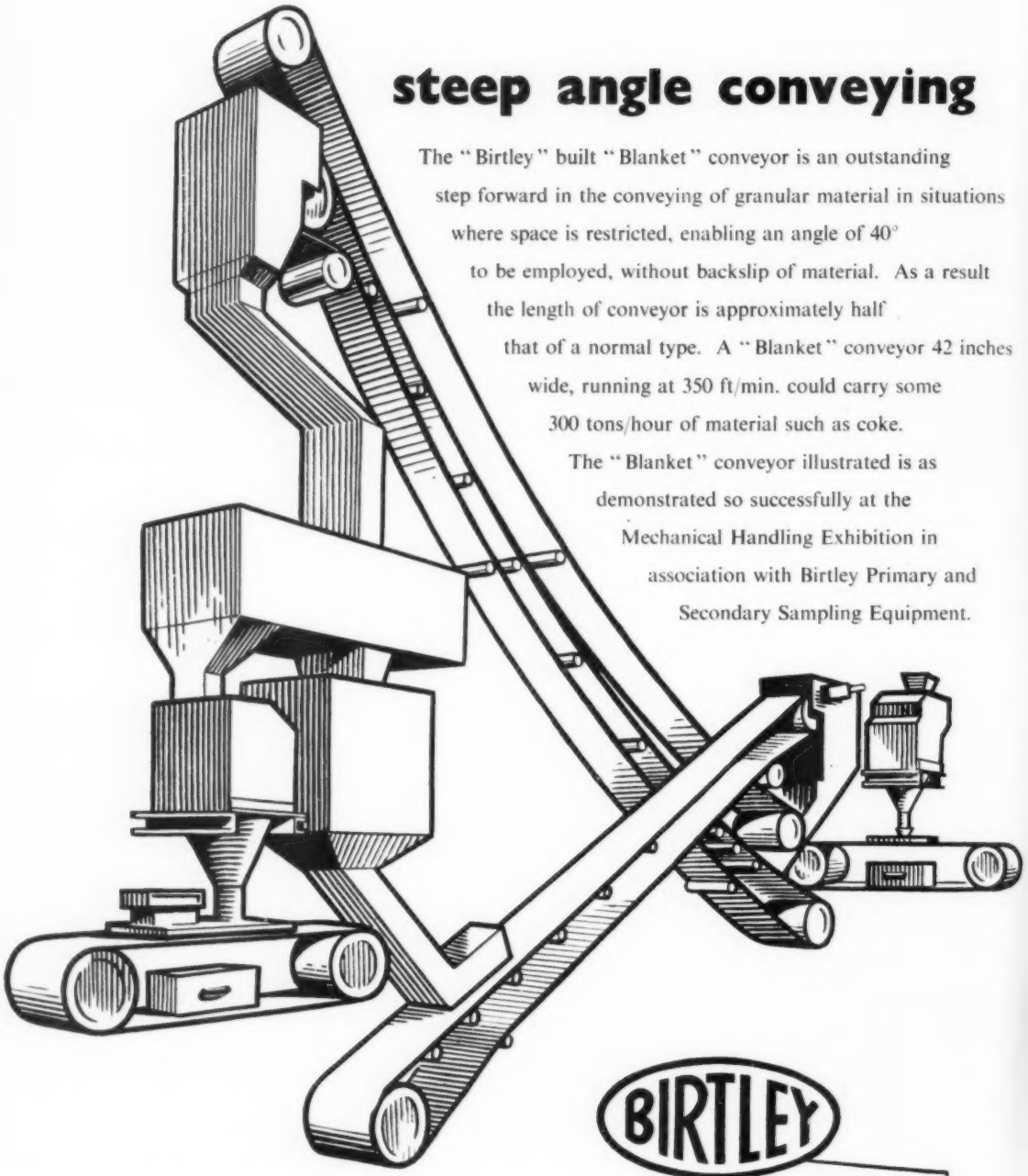

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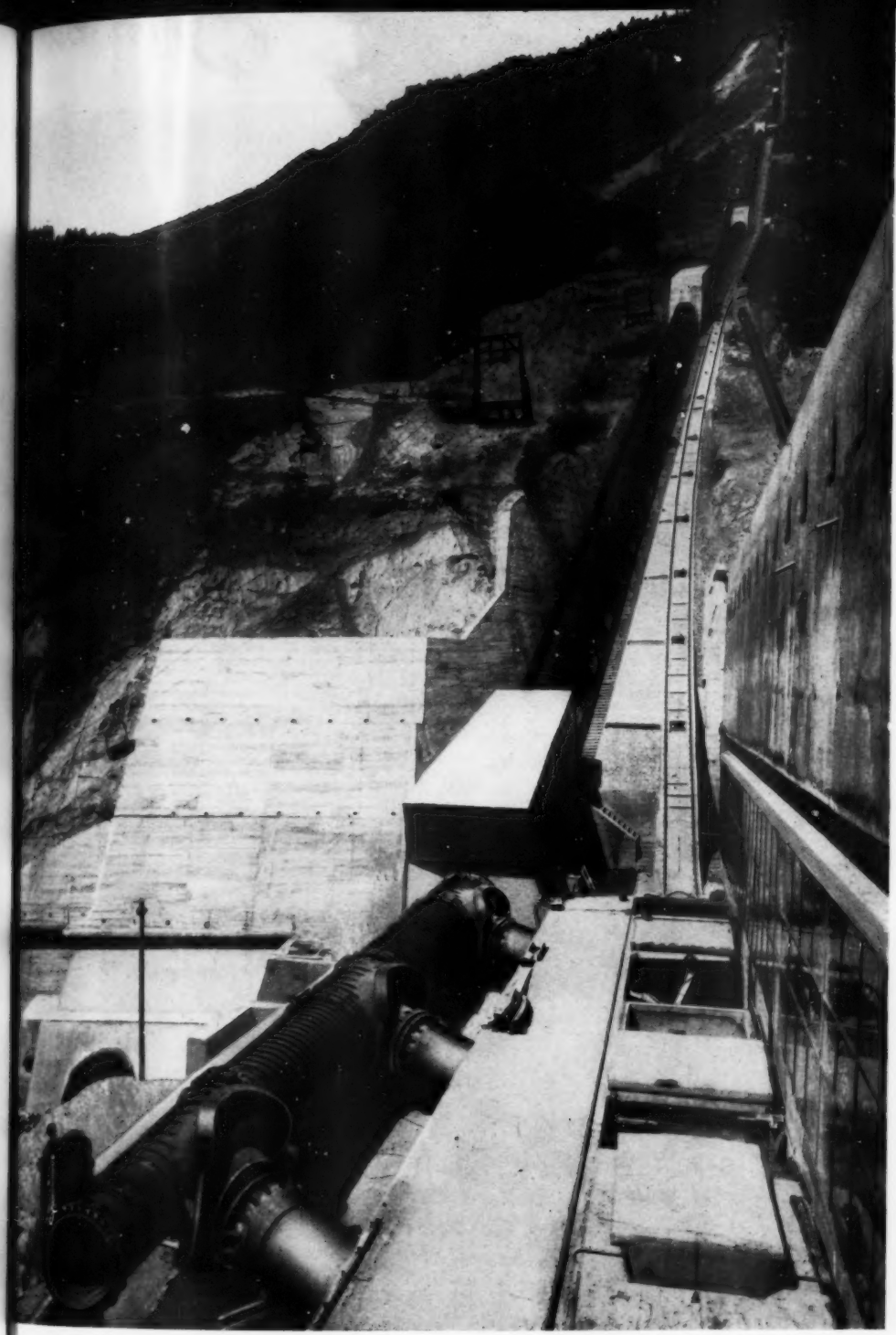

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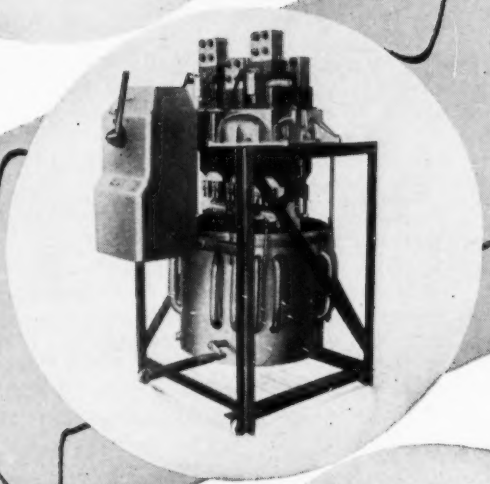
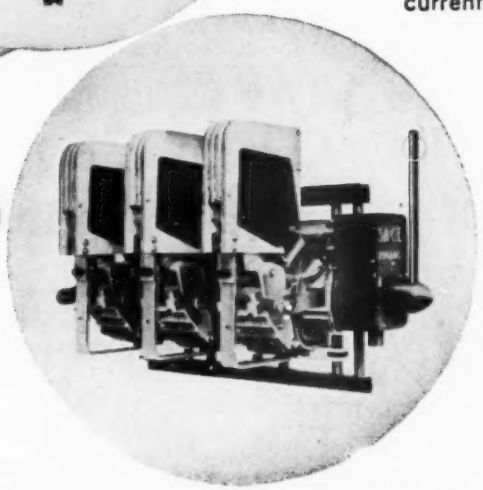


...in cassa d'olio
tensioni fino a 35 kV
correnti fino a 12 000 A

...oil tank type
voltages up to 35 kV
currents up to 12 000 A



...in aria
tensioni fino a 600 V
correnti fino a 4 000 A

...air type
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currents up to 4 000 A

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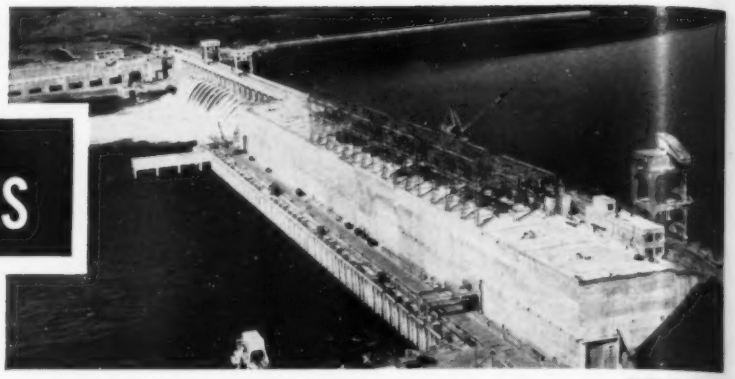
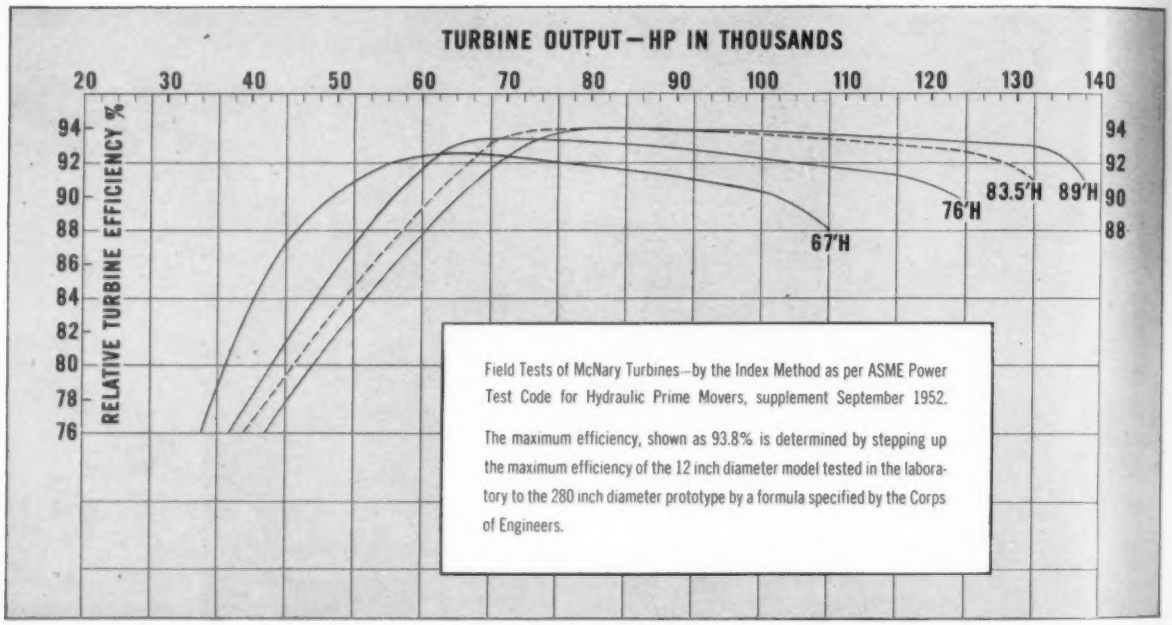
SMS

KAPLAN TURBINES



McNary Dam


TURBINE OUTPUT—HP IN THOUSANDS
20 30 40 50 60 70 80 90 100 110 120 130 140
RELATIVE TURBINE EFFICIENCY %
94 92 90 88 86 84 82 80 78 76
94 92 90 88
83.5'H
89'H
76'H
67'H
Field Tests of McNary Turbines—by the Index Method as per ASME Power Test Code for Hydraulic Prime Movers, supplement September 1952.
The maximum efficiency, shown as 93.8% is determined by stepping up the maximum efficiency of the 12 inch diameter model tested in the laboratory to the 280 inch diameter prototype by a formula specified by the Corps of Engineers.

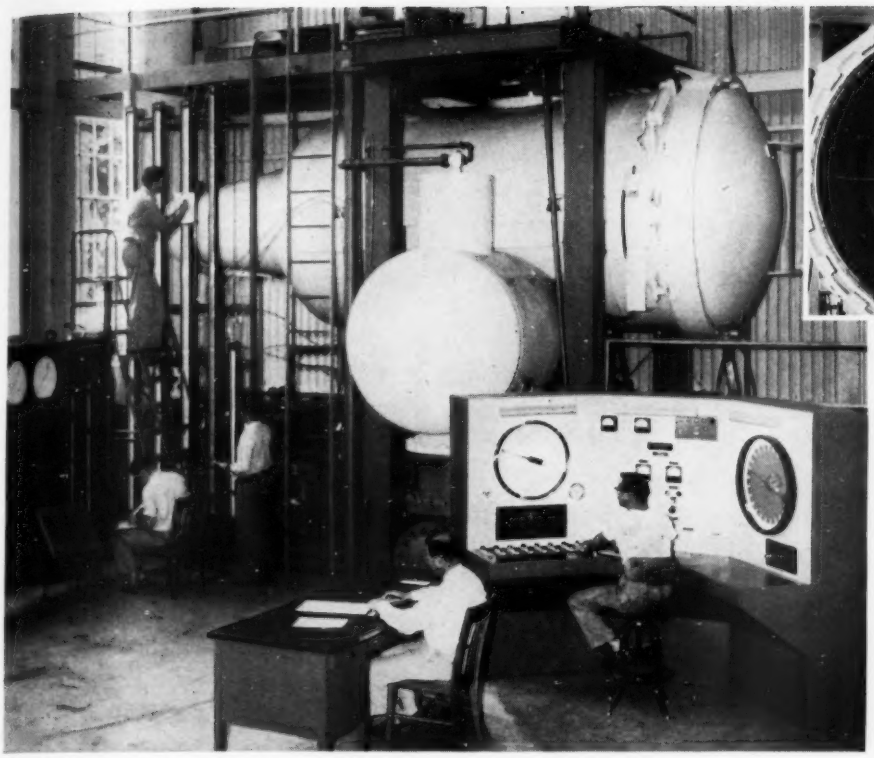
MOST POWERFUL KAPLAN TURBINES AT ICE HARBOR

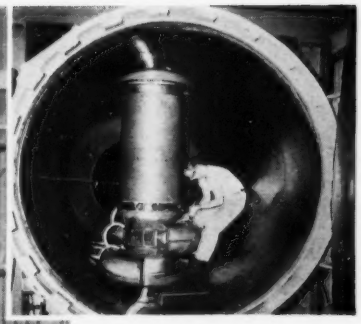
SMS Kaplan turbines at Ice Harbor Lock and Dam will be the most powerful of this type in the world. The output will exceed even that at McNary shown by the above field test curves.

As a result of additional research in the SMS high head turbine test stand with homologous model of the prototype, the output and efficiency of the Ice Harbor turbines will surpass McNary. Prototype performance will be checked by the Index Method, with turbine efficiency guarantees based on the 12″ model tests.

The Ice Harbor turbines are rated at 143,000 HP under 89 ft. net effective head and will normally operate under heads from 78 ft. to 102.5 ft. maximum at a speed of 90 R.P.M. They are being built for the U. S. Army, Corps of Engineers, Walla Walla District, for a site on the Snake River in Washington.

From the laboratory model to the prototype unit, the outstanding performance characteristics of these turbines are a typical result of the specialized research, engineering experience and productive capacity that is ready to serve you at S. Morgan Smith Company. Write to us at York, Pa., U.S.A., for full information on hydraulic turbines, or valves, gates, hoists and other accessories.





A complete model turbine wheel case assembly, built to extreme accuracy, is shown being mounted in the testing chamber.

New high head test stand in the SMS Hydraulic Laboratory, including control panel and gages.

High Head Turbine Test Stand At SMS Laboratory DUPLICATES FIELD CONDITIONS

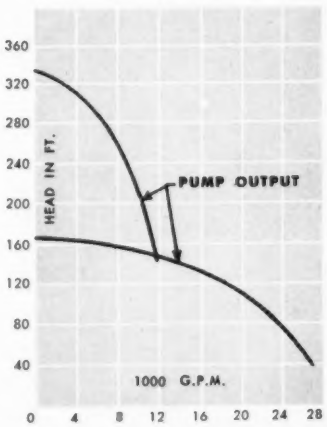
With the addition of its new high head test stand, the SMS Hydraulic Laboratory can now test homologous model turbines under controlled conditions that *duplicate* those found in the prototype installations. This is a substantial stride forward in hydraulic turbine research, since the complete reproduction of actual field conditions has not previously been possible.

The outstanding features of this new facility are:

- World's highest artificial testing head.
- Flows of 5,000 g.p.m. under 300-foot head, and 21,000 g.p.m. under 100-foot head.
- 300 H.P., 0 to 6,000 R.P.M., eddy current dynamometer.
- 100-ton water cooling system to maintain prototype water temperature.

Both basic research and formal contract acceptance tests are performed here. Test stand equipment permits testing of all Kaplan and Propeller, as well as many Francis turbine designs, under conditions of *head* and sigma that *duplicate* those found in the field. This provides a high degree of testing accuracy and permits accurate testing of settings that cannot be satisfactorily field tested.

For further information on the significance of this high head test stand, write to S. Morgan Smith Co., York, Pa.



Pump Head-discharge Curves for Series and Parallel Operation.

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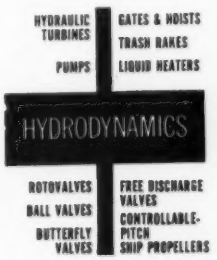

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Very often it is possible to economise on known standard constructions, and we strongly recommend you to submit problems to our engineers so that the most economical solution can be employed.

We are interested in your particular problem, and are prepared to fabricate bridges and structures to your own individual designs.

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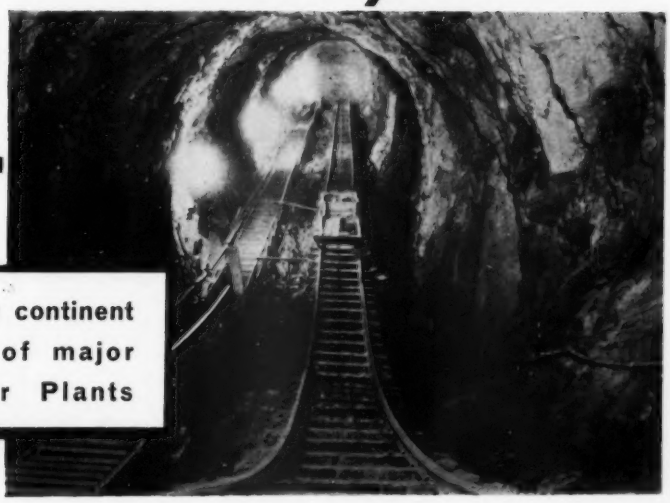
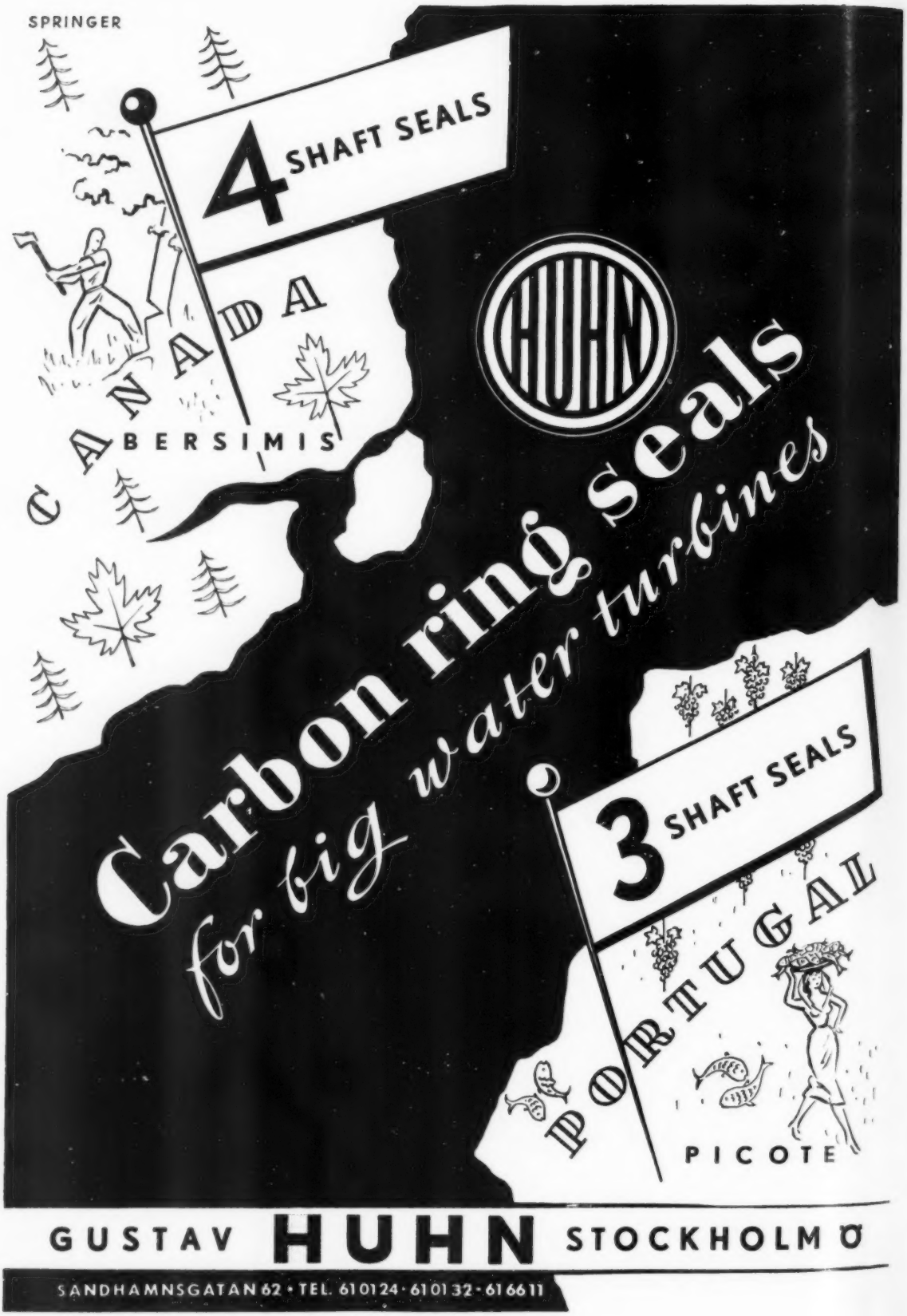


...are engaged on every continent in the development of major Hydro-Electric Power Plants



GUSTAV **HUHN** STOCKHOLM Ö

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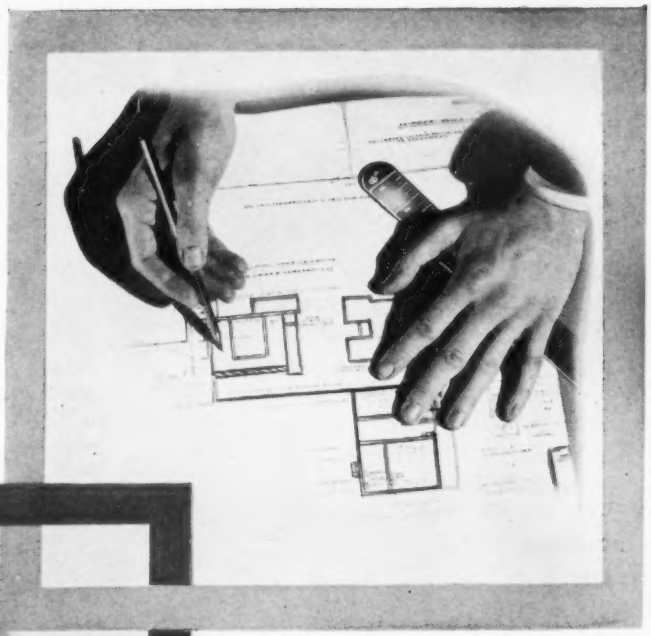
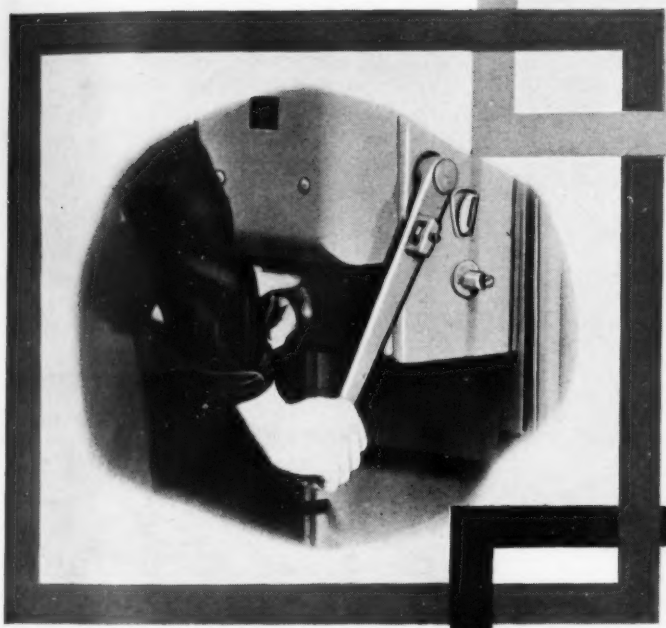
From drawing board





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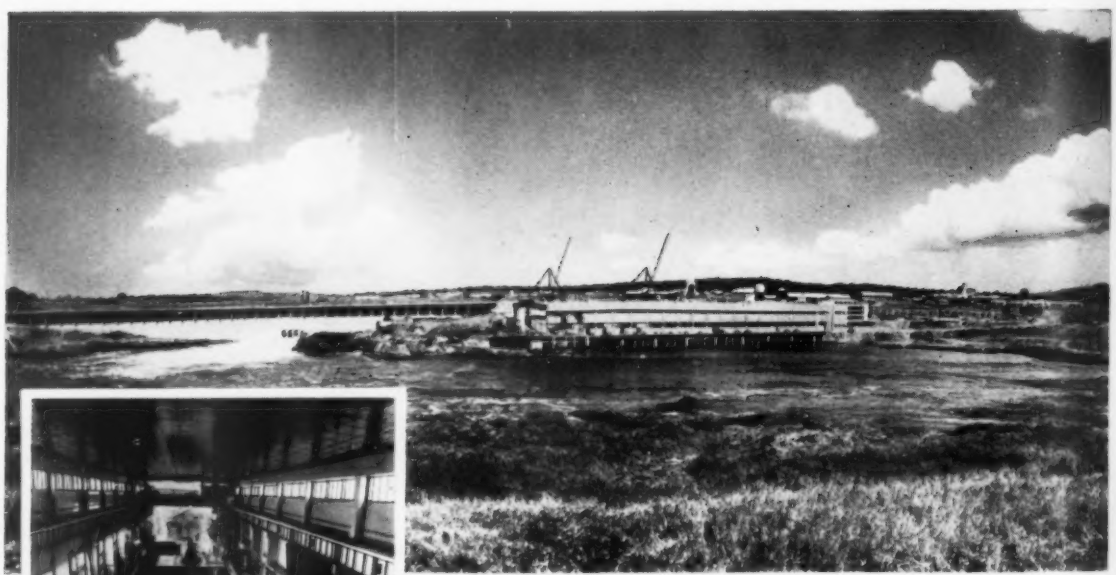
HYDRO-ELECTRIC EQUIPMENT

Power for Uganda by

The development of electric power for the Protectorate of Uganda ranks among many notable British achievements in which BTH has played a part. Bordering on Lake Victoria and divided by the Nile, Uganda covers an area of almost 94,000 sq. miles and has a population of over 4 millions. Here, as in countries throughout the world, BTH equipment is helping to produce power for greater prosperity, by harnessing natural resources of energy.



The first three BTH alternators in service.

The great hydro-electric project at Owen Falls includes eight BTH 16,700-kVA, 11,000-V vertical shaft alternators driven by Boving Kaplan turbines. BTH are also supplying electronic-amplidyne voltage regulators, control gear and ancillary equipment, 11-kV switchgear, and 20,000-kVA 33/132-kV transformers.

BRITISH THOMSON-HOUSTON

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A crew averaging 17 men, using a minimum of special equipment, moved the pipe sections into position from the car to the concrete pier saddles. Engineering and construction was by Ebasco Services, Incorporated.

The 30-ft pipe lengths were transported to the site from a railhead at Carhuamayo by truck-trailer over a 60-mile tortuous mountain road to a point near the surge tank. From there, pipe sections were lowered downhill, into position by means of an inclined railway running parallel to the course of the penstock.

Steel Penstock Harnesses Paucartambo River for Peru's Latest Hydroelectric Power Plant

In Peru, as in all the other rapidly growing countries of South America, electric power is one of the vital keys to progress. Projects like the harnessing of Peru's Paucartambo River by the Cerro de Pasco Corp. are opening the door to industrial expansion and higher standards of living.

Lifeline of this modern power station is a 4,600-ft penstock in diameters from 74" to 80", made possible by the use of steel pipe and Dresser Couplings. Total vertical drop from a high-level supply tunnel to the power station below is 1,550 ft.

The pipe wall thickness ranges from 7/16" at the top to 1 13/16" at the bottom where the line gives bottle-tight service under a 1,730-ft static head.

Dresser Penstock Couplings made it possible to eliminate expansion joints and follow the terrain with a minimum of grading. Since the penstock is located in an earthquake area, the resilience of Dresser gaskets gives extra insurance against damage by earthquake shock.

With the pipe in place in the saddles, wrenches were the only tools needed to seal the Dresser Couplings, forming dependable, permanently tight joints.

The fast, easy installation through the use of Dresser Couplings permitted completion well within the allotted time schedule and estimated cost.

For useful engineering data on other successful Dresser-Coupled steel penstock installations, send for new illustrated penstock brochure. Write: Dresser Manufacturing Division, Bradford, Pa., U.S.A.

ONE OF THE DRESSER INDUSTRIES

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CABLEWAYS

17 POHLIG – Cableways
with spans up to 2800 ft.
and lifting heights up to 900 ft.,
travelling speeds up to 1200 ft. per minute
and a carrying capacity
of up to 20 tons per each cableway
have been erected and commissioned
during the last 6 years
by our company
in Switzerland

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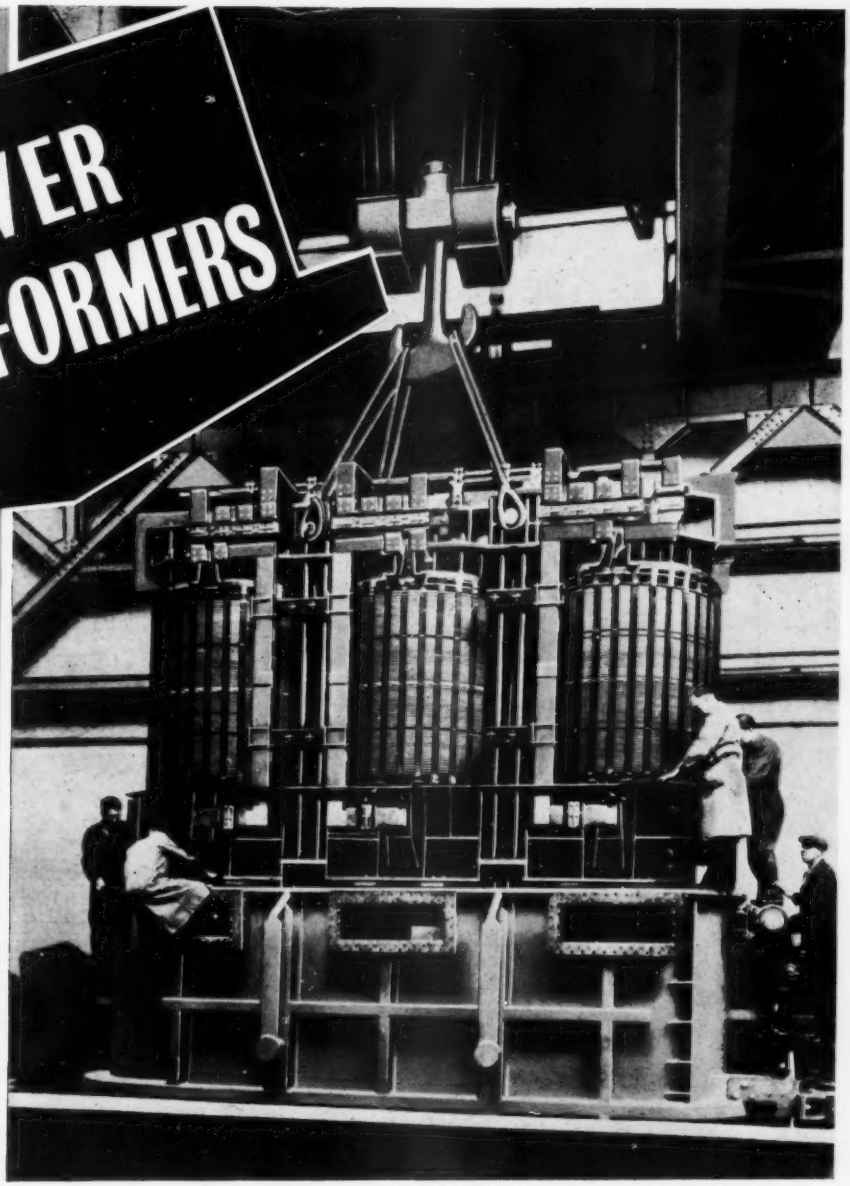
POWER TRANSFORMERS



The millions of kVA of Bruce Peebles Transformers in successful operation today constitute a reliable guide in selecting transformers to meet the demands of tomorrow.

Bruce Peebles manufacture power transformers in the largest sizes for service at all voltages. Typical units in course of manufacture are 120,000 kVA 275,000-volt auto-transformers for the British Super-Grid.

Illustration shows a 75,000 kVA generator transformer in course of erection. It is typical of numbers ordered for direct connection to the generator to operate as a combined unit.

BRUCE PEEBLES

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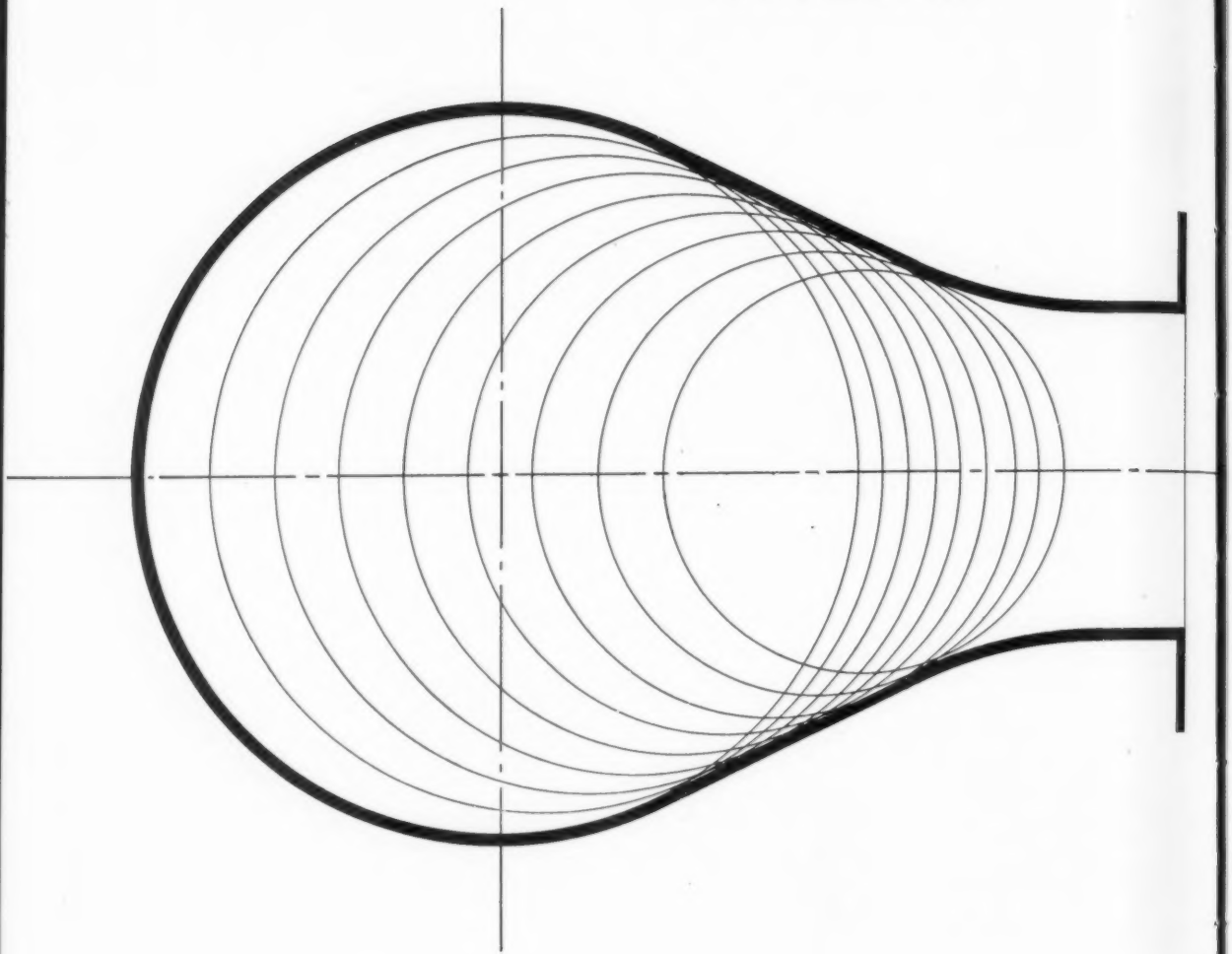

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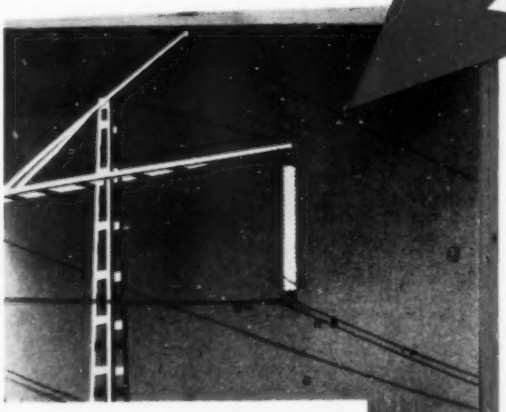
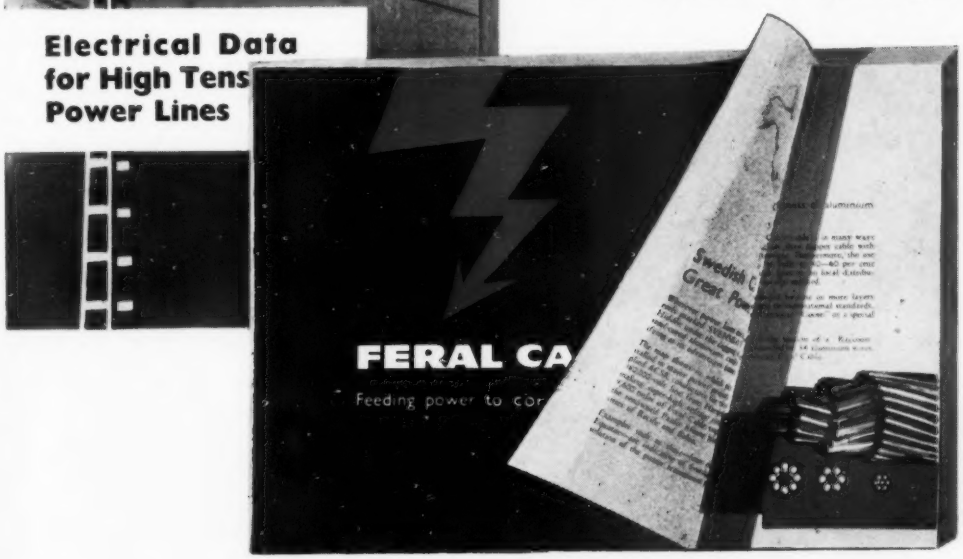
Works: ARZIGNANO VICENZA LONIGO MONTEBELLO MONTECCHIO Italy

2 GUIDES TO TODAY'S HIGHWAY FOR POWER



Electrical Data for High Tension Power Lines. *In 32 pages of text and diagrams leading experts of the Swedish State Power Board give calculation data and formulas for selecting conductors and arranging them in power lines.*

Feral Cable. *New booklet telling of Svenska Metallverken's plant at Västerås where renowned Swedish steel-cored aluminium conductor is produced in any required length.*



For those thinking about new power lines, these two booklets complement each other. The one describes the unique manufacturing facilities for making Feral Cable. It also tells of recent big power projects in various parts of the world where Feral Cable has been used for the transmission lines. The other is a technical paper written as a guide for engineers in selecting conductors for power lines. The authors are two leading Swedish power engineers—men who have themselves helped design and build Sweden's record-breaking power network.

Both publications can be obtained by writing to AB Svenska Metallverken, Feral Cable Division, Västerås, Sweden.

AB SVENSKA METALLVERKEN

Manufacturers of **FERAL CABLE**: *Today's Highway for Power*

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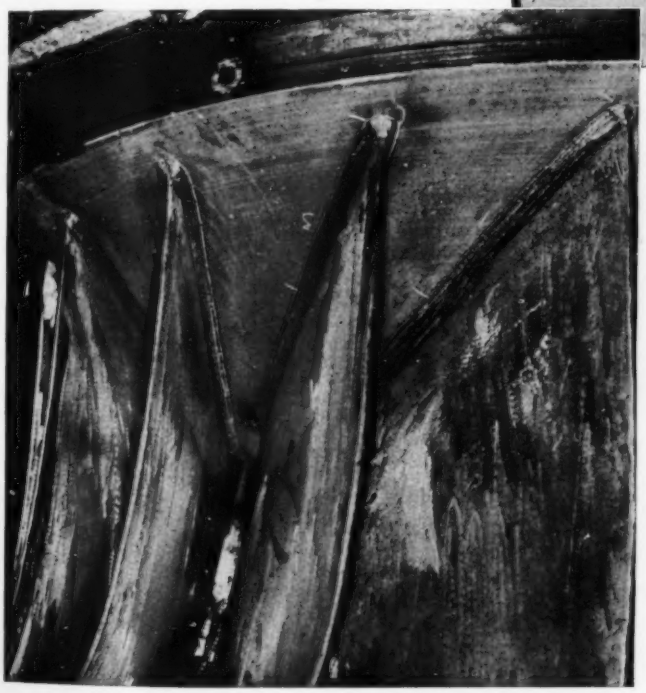
Sécheron production is renowned for quality.

S.A. DES ATELIERS DE SÉCHERON / GENEVA

Modern construction of Francis runners

The runner shown on these pictures is of *welded* construction with blades and rim of stainless steel (Chromium 13%) and hub of plain carbon steel. The welding is effected according to a new, simple method using electrical induction for the necessary pre-heating. On this runner the welding results have been most successful.

Welded joints before final grinding.



Our normal design of *welded* Francis runners

KMW also manufacture Francis runners of welded construction according to their patented method. In this case the runners are made of plain carbon steel with only those parts which may be exposed to cavitation damage coated with corrosion resistant material. The coating is effected in a simple and reliable way before welding the various parts together. By this means the manufacturing costs are appreciably reduced.

Further advantages with *welded* construction: Great accuracy in manufacture. All surfaces in the waterways completely finished before assembly of the runner.

Up to now we have manufactured about 35 runners of diameters up to 16 feet and for heads up to 305 feet using this method.

AKTIEBOLAGET KARLSTADS MEKANISKA WERKSTAI

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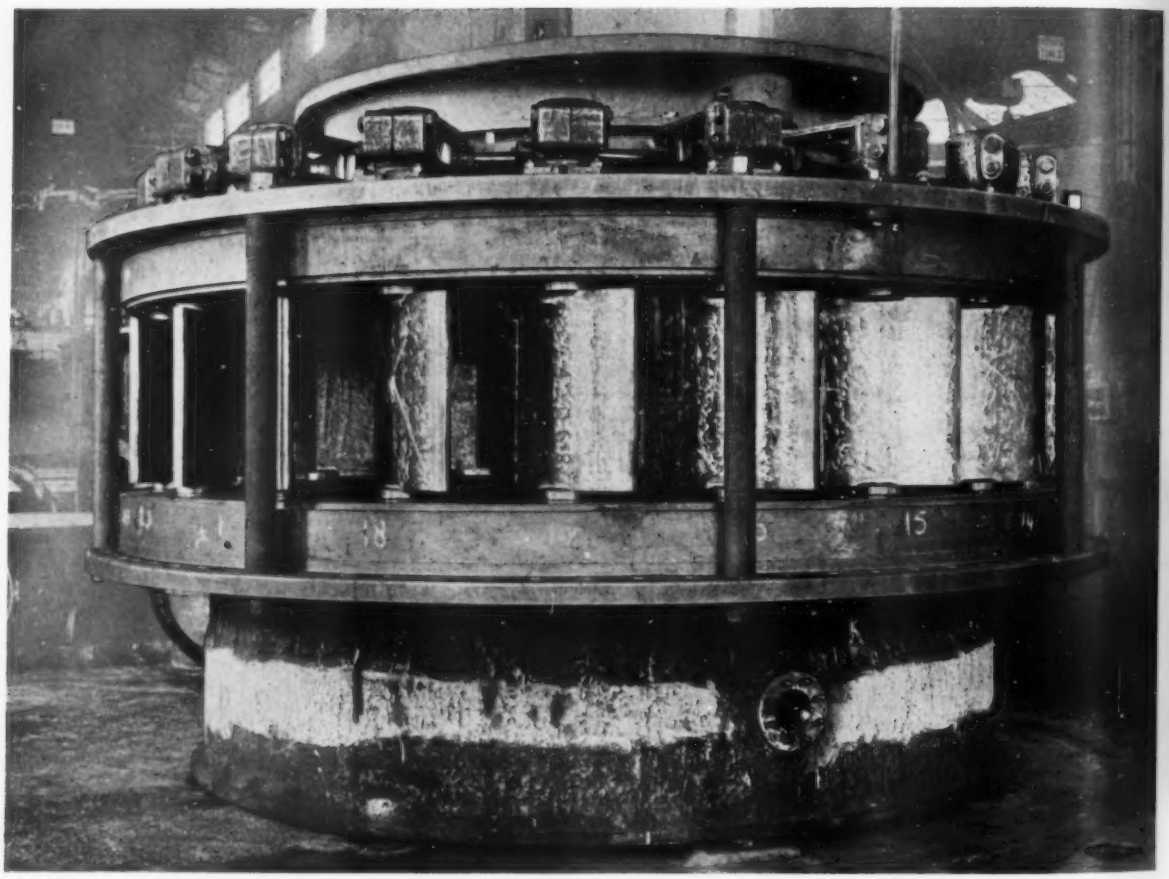
FRANCO TOSI S.p.a ★ LEGNANO (ITALY)

HYDRAULIC TURBINES

KAPLAN ★ FRANCIS ★ PELTON ★ GOVERNORS ★ VALVES



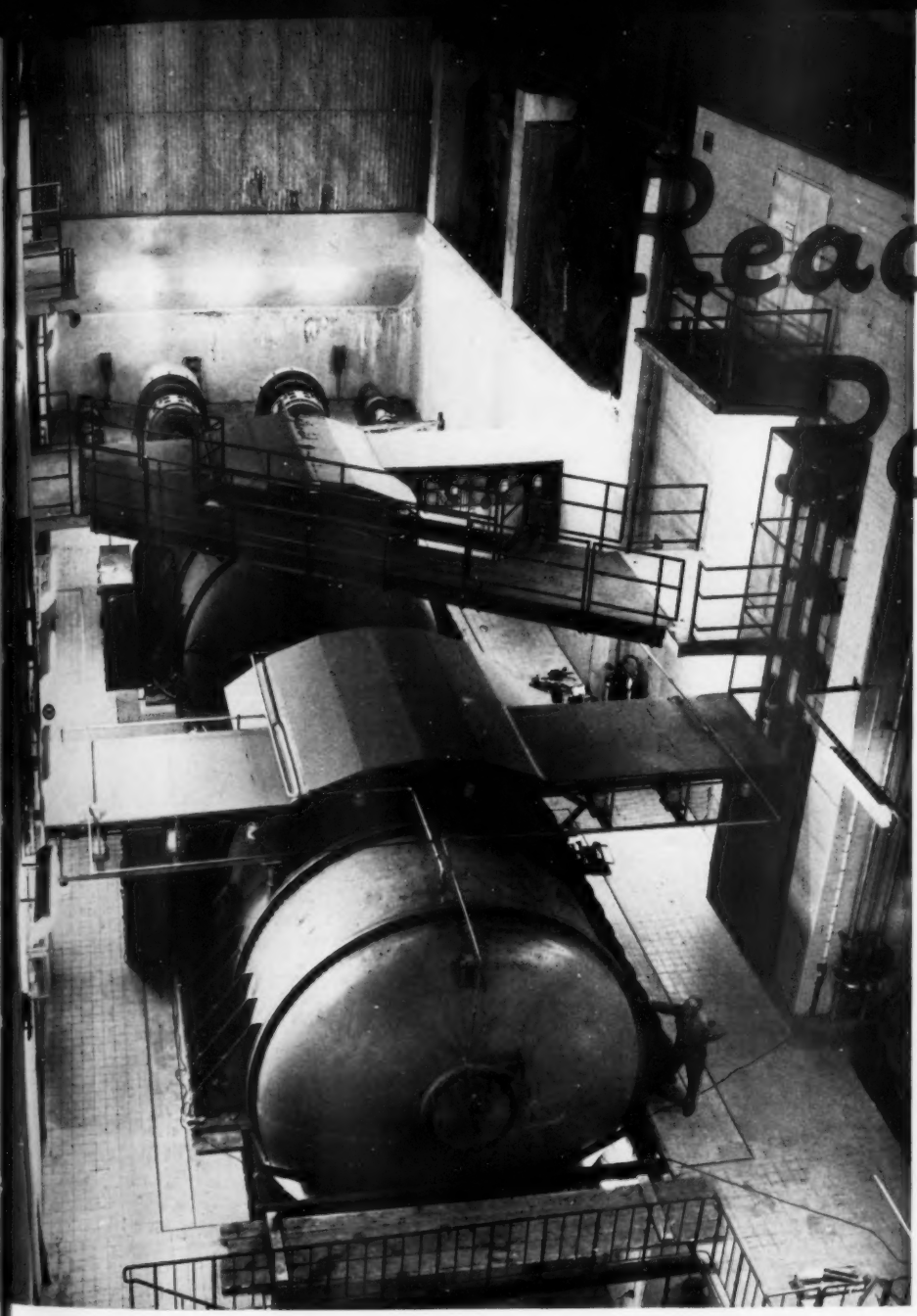
Upper and lower casings with deflector vanes and operating mechanisms.

ELECTRICITÉ DE FRANCE — PARIS

ST. PIERRE COGNET HYDRO-ELECTRIC STATION

Francis turbine rated for 46,500 kW. Capacity 60 cu.m./sec. Head 88 mt. Speed 214 r.p.m.

Reactive Power



Stability and voltage control of large high-voltage transmission systems require equipment for large amounts of reactive power.

For the Swedish State Power Board's 380 kV system with a total line length of about 1,700 miles, ASEA have supplied all the synchronous condensers, all the shunt reactors and two-thirds of the series capacitors.

The ASEA deliveries comprised, in all :

Synchronous Condensers	± 225 MVAr
Series Capacitors	+ 200 MVAr
Shunt Reactors	− 900 MVAr

The picture shows a view of a subterranean station with two hydrogen-cooled condensers, each machine having the following main data :

Rated power : 75 MVA

Maximum continuous output at 15 lb./sq. in. gauge pressure: leading 100 MVAr
lagging 75 MVAr

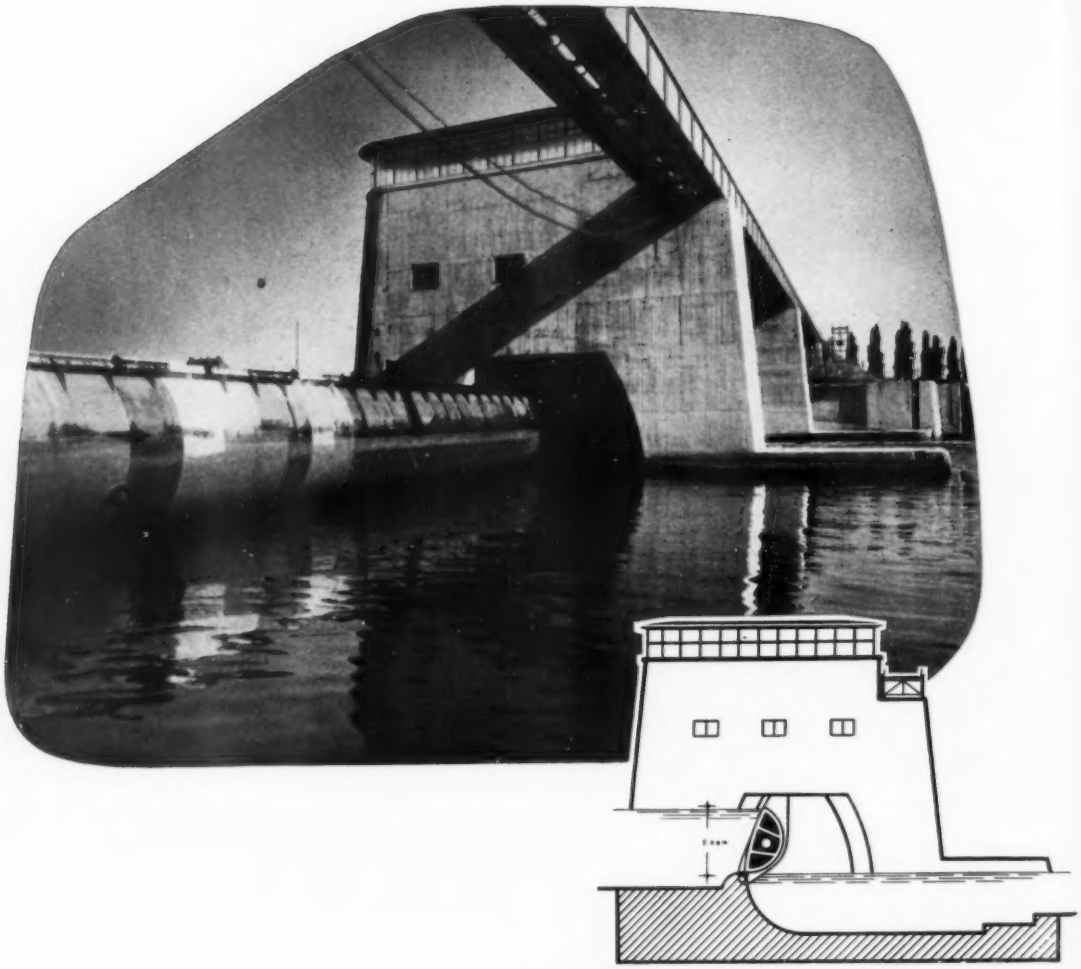
Speed : 750 r/m

Voltage : 19-21 kV

For the solution of your power transmission problems consult

Map of Sweden showing the 380 kV transmission system

Västerås **ASEA** Sweden



A height of retention of 5 metres and 40 metres clear width are the characteristic dimensions of the largest fishbelly flap hitherto built. This type of gate is the result of elaborate tests in MAN's own laboratory, where actual site conditions can be reproduced to scale.

M·A·N

HYDRAULIC STRUCTURES

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AWCO produces :

STRANDED ELECTRICAL CONDUCTORS in all-aluminium, steel-cored aluminium and Silmalec (aluminium alloy)

WIRE for the manufacture of insulated cables

WIRE for aircraft and general engineering

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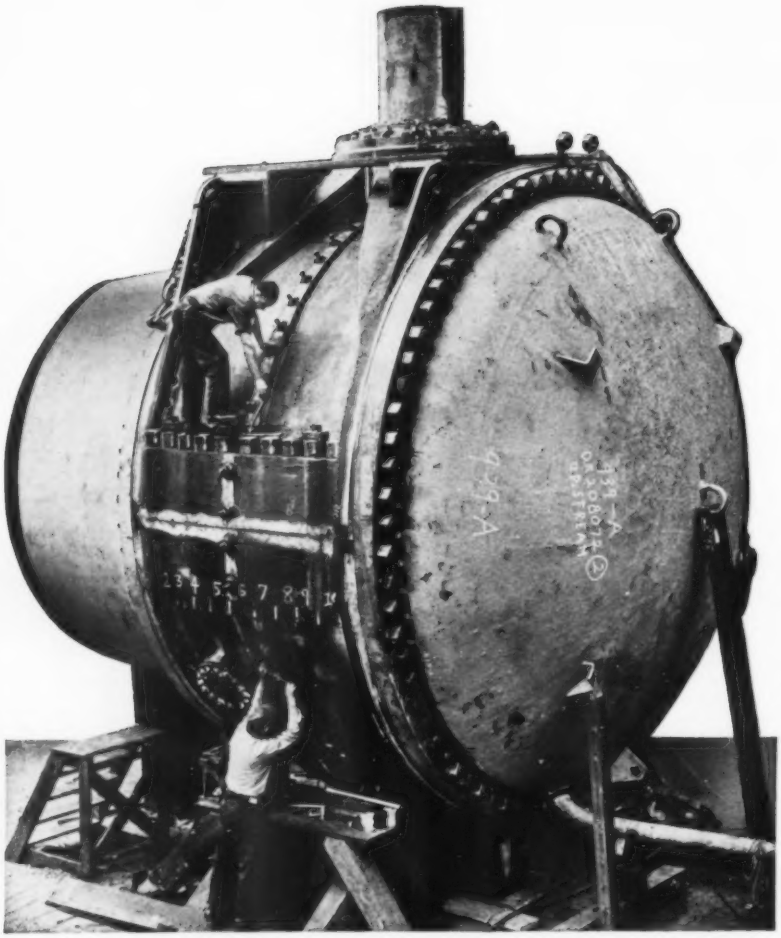


This 16-Foot Butterfly Valve illustrates the type of work which Newport News takes in stride. Newport News built 3 such valves, each weighing 446,000 lbs., for the Ross Power Plant, Skagit Project, Department of Light, City of Seattle, Washington. Designed for a water flow of 3,620 cu. ft. per sec., and a hydrostatic pressure of 290 psi., these valves were shop tested by Newport News at 450 psi. They are hydraulically operated with oil at 1,500 psi. pressure. Shop tests assure speedy, trouble-free assembly of Newport News built equipment, on the site.

The TEST of a TITAN

Here is one of the largest high head butterfly valves ever built, undergoing a shop test at Newport News. If you had an opportunity to follow this unit from start to finish, you would see *first hand* how Newport News produces massive equipment *economically*. For economy is a basic advantage that results from Newport News' high integration of skill and production facilities.

Large engineering and technical staffs, operating a plant comprising acres of brass, iron and steel foundries, five huge machine shops and other extensive fabricating facilities, have made Newport News one of the world's largest producers of hydraulic turbines, valves, gates, penstocks and other essential equipment... both standard and special in design.

Let us bid on your equipment. Write us today for your copy of *"Water Power Equipment."*

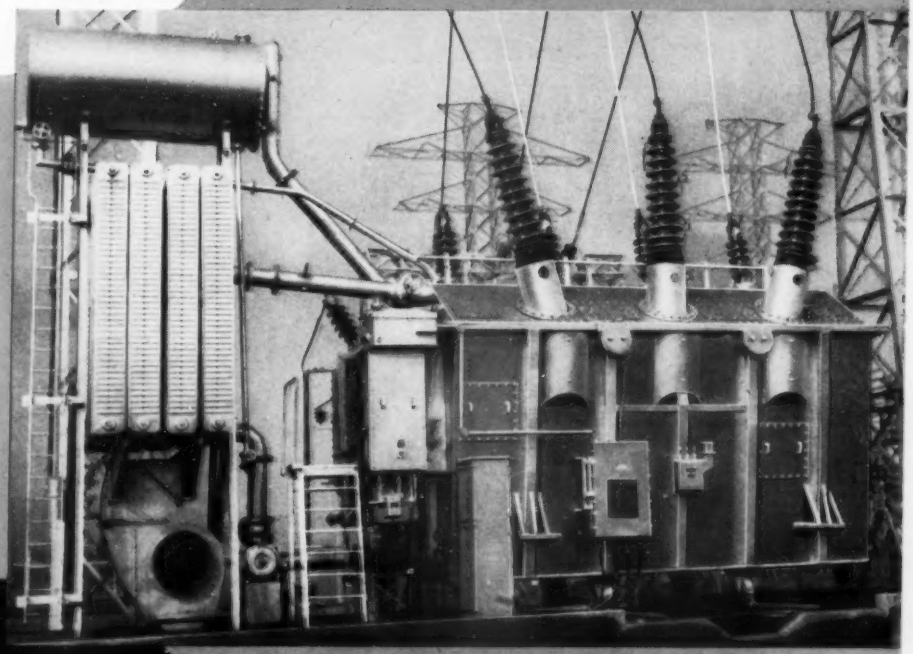
NEWPORT NEWS

SHIPBUILDING AND DRY DOCK COMPANY
Newport News, Virginia

FERRANTI TRANSFORMERS

for the DAMODAR VALLEY HYDRO-ELECTRIC SCHEME

One of the three 20,000 kVA ON/OFB 3 phase 50 cycles 132/66-33 kV Ferranti Transformers with on-load tap changing gear on site.



FERRANTI TRANSFORMERS ARE FAMOUS THROUGHOUT THE WORLD

With a capacity of over 5 million kVA per annum the Ferranti Transformer Factory at Hollinwood produces Power Transformers of the highest voltage and rating for vast engineering projects all over the world. Amongst these projects is the Damodar Valley Hydro-Electric Scheme for which Ferranti Ltd. have supplied

THREE	20,000 kVA ON/OFB 3 phase 50 cycles 132/66-33 kV Transformers with on-load tap changing gear,
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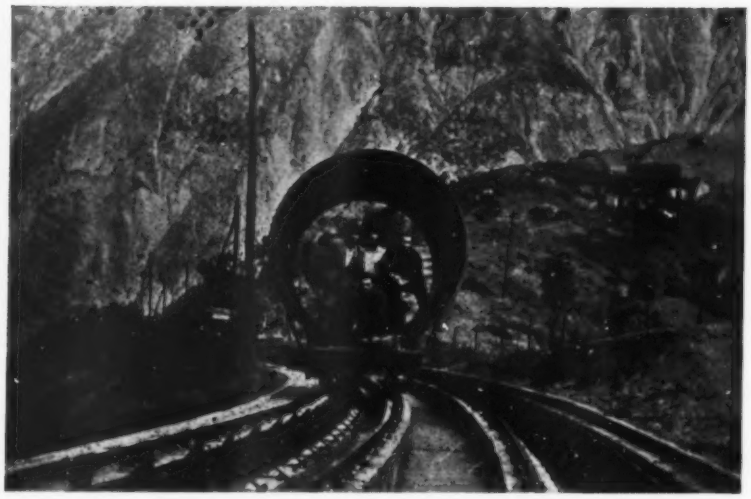

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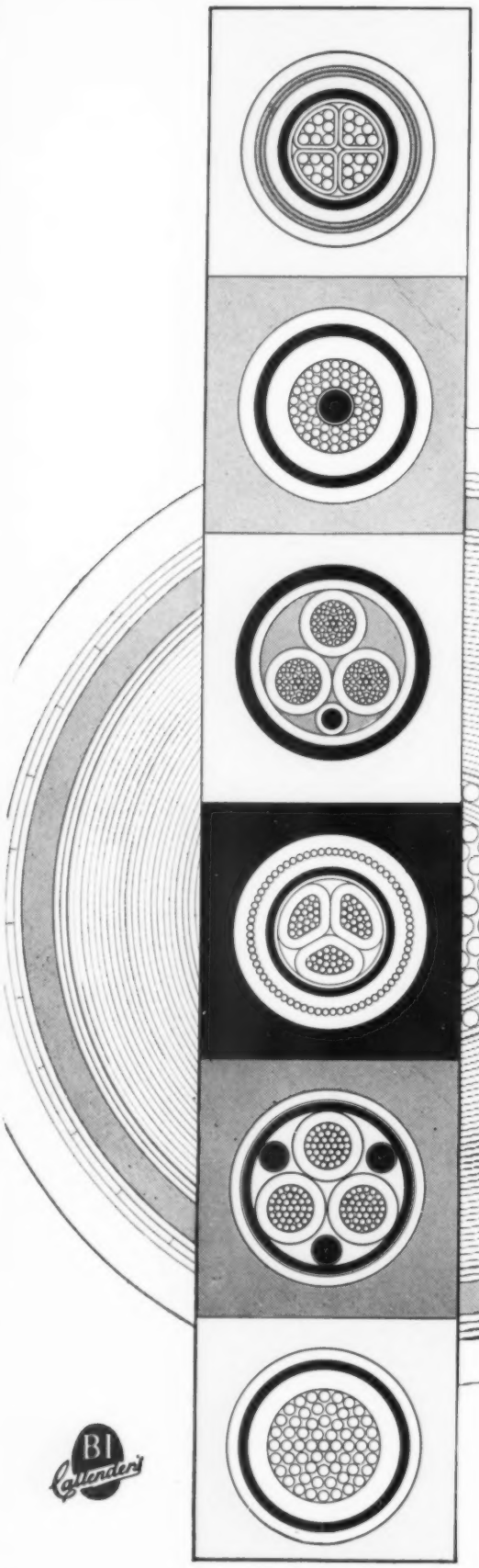

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Hydraulic Research at East Kilbride

HYDRAULIC research sponsored by the Department of Scientific and Industrial Research falls into two general classes, conducted by separate organisations. River, estuary, coastal and similar problems are the responsibility of the Hydraulics Research Station at Wallingford under Sir Claude Inglis, whereas problems relating to the mechanics of fluids and to hydraulic machinery, including turbines and pumps, are investigated by the Mechanical Engineering Research Laboratory under the direction of Dr. D. G. Sopwith at East Kilbride. A rough distinction would appear to be that Wallingford deals with conditions of free flow whereas East Kilbride is interested in problems of flow where there is no free surface.

Both laboratories have recently published their Annual Reports for 1955, and we referred to the Hydraulics Research Board Report in our August issue. The Report of the Mechanical Engineering Research Board* naturally records progress in all the seven Divisions comprising the organisation, but the section dealing with the work of the Fluids Division under Dr. S. P. Hutton is of more than ordinary interest, for it describes the equipment in the new hydraulic machinery building which is now approaching completion. Much, if not most, of the equipment has been designed by the staff of the Division, and incorporates features that are probably unique in research equipment. Seeing that much of the research will be on models, a careful balance has had to be struck between a scale large enough to give a satisfactory correlation between model and prototype and small enough to be economic in its claims on building space. The compromise has led to a building with a working floor area of more than 28,000 sq. ft., and careful design of the pipe circuits, including the use of cascade bends, has made it possible to fit a large quantity of equipment into this space. Much of the novel research equipment has been designed on the basis of scale tests to ensure optimum performance.

From our standpoint we would give pride of place to the variable-pressure closed circuit for cavitation research on water turbines, which has facilities for controlling the pressure, air content, and temperature of the water and will be one of the largest and most advanced water tunnels of its kind in the world. It will accept turbine models up to 20 in. runner diameter and 250 h.p., and can impose heads up to 200 ft., and thus can test high-head axial-flow propeller turbines at the same head as the full-scale installation. The circuit comprises a nozzle for smoothing the flow and for flow measurement; the turbine on test with an elbow draft tube; a vertical circular pipe leading to an axial-flow pump for driving the water round the circuit when low heads are being used, the maximum flow then being 19,000 g.p.m. (about 50 cusecs); a 60 ft.-deep reabsorber to keep the dissolved air content of the water constant; and a cascade leading back to the nozzle. For tests at high heads up to 200 ft., a centrifugal pump can be connected after the reabsorber.

A somewhat similar water tunnel has been installed for cavitation research on pumps, which can accommodate centrifugal or mixed-flow pumps up to 20 in. inlet diameter, with a maximum head of 600 ft., flow rates up to 7,500 g.p.m., and power inputs up to 350 h.p. The circuit has a capacity of 32,000 gallons and comprises a vertical cylindrical suction tank to control the suction lift; the pump on test; a valve to reduce the head from 600 ft. to 80 ft.; a reabsorber; venturimeters for flow measurement; and entry to the suction tank through a second valve which drops the head from 80 ft. to the suction-inlet pressure. Model tests were made on the suction tank to ensure a good flow distribution at the pump inlet. The air content of the water may be varied and the absolute static-pressure level controlled to give a variety of cavitation conditions. If desired, the temperature of the water in the circuit can be kept between 60 and 65° F.

The third major hydraulic test installation is the open-circuit test bay, which is 120 ft. long by 50 ft.

* "Mechanical Engineering Research, 1955." Published for the Department of Scientific and Industrial Research by H.M. Stationery Office. Price 4s. net.

wide, and contains a 60,000 gallon covered sump. Service pumps deliver up to 11,000 g.p.m. to a constant-head tank 45 ft. above sump level. The weir in the tank, which is of a concertina shape to give an effective length of 120 ft., enables the head to be maintained constant within $\pm \frac{1}{8}$ in. for flows from zero to 11,000 g.p.m. The tank provides a supply of water for open-circuit tests for studying the performance of model turbines, flowmeters, pipes, valves, and other equipment associated with hydraulic machinery. Alternatively, water can be pumped to a variable-head tank in which a telescopic weir is used to set the head at any value between 12 and 40 ft. above the sump water level. Pumps may be mounted above this tank and tested under suction inlet pressures down to 5 ft. of water absolute.

The water from these circuits returns either directly to the sump or through flow measurement lines. These will also be used for calibrating laboratory substandards and industrial flowmeters up to 18 in. in diameter, at rates of flow up to 11,000 g.p.m. The rate of flow is measured by diverting the return flow to the sump into a weighing tank for a known time; a 30 ton tank is used for the largest flows. The water may also be made to flow through a 700 ft. loop of pipe, 20 in. in diameter, in the laboratory grounds; this will be used for measuring friction losses in pipes and for tests on large-scale flow-measurement techniques. The sump was designed on the basis of model tests, and is fitted with baffle plates to reduce wave and vortex action. Pumps can be mounted on bedplates directly above the sump and the suction intake observed through windows in the side of the sump which is fitted with under-water lighting.

One of the significant changes of thought in the research field in recent years has been the better appreciation of the correlation existing between apparently unconnected lines of research; for instance, aeronautical research has introduced new conceptions into the design of steam turbines and of hydraulic appliances. This is fully appreciated at East Kilbride, for the facilities include an aerodynamics laboratory, where models of pumps and turbines are tested with air instead of water as the working fluid. Relatively inexpensive wood or sheet-metal models, which can be easily modified, are used to provide information about the flow patterns before the final model is tested with water.

Special electric driving and absorption dynamometers, ranging from 10 to 350 h.p., have been designed for measuring losses in hydraulic machinery. Some have vertical shafts, others horizontal; one 200 h.p. machine can run either horizontally or vertically; oil-lift bearings are used to minimise friction.

There is also an oil and special fluids laboratory for work on oil hydraulic systems.

Naturally, over the past few years much of the time of the laboratory staff has been taken up with the design and installation of the special equipment we have briefly outlined, although research and advisory work has been maintained. It is hoped that the laboratory will be fully equipped before the end of this year, and we look forward to East Kilbride making a valuable contribution to our knowledge of the phenomena of cavitation in turbines and pumps, of the techniques of flow measurement and of turbine and pump testing, and of many other problems associated with hydraulic apparatus.

Kariba Contracts

A CONTRACT for the construction of the Kariba dam, together with other ancillary civil-engineering work, has been awarded to an Italian firm, Impresit South Africa (Proprietary) Ltd., who are to form a subsidiary, Impresit (Kariba) (Pvt) Ltd., to carry out the actual work. The Italian firms composing this new company are Dott. Ing. Guiseppe Torno & Co. S.p.A., Impresa Ing. Lodigiani S.p.A., Imprese Italiane All'Estero S.p.A., Impresa Umberto Girola S.p.A., and Impresit Rhodesia (Proprietary) Ltd. It is understood that this contract exceeds £25 million, and a further contract for the transmission lines, worth nearly £10 million, has been awarded to Rhodesian Power Lines (Pvt) Ltd., the Rhodesian associate of Societa Anomina Elettrificazione of Milan.

Contracts for the 140,000 h.p. turbines go to Boving & Co. Ltd. (£1,072,583); for the 100 MW generators to Metropolitan-Vickers Export Co. Ltd. (£1,772,065); for the power-station transformers to The English Electric Co. Ltd. (£622,500); for the substation transformers to Ferranti Ltd. (£1,333,200); for the overhead travelling crane to Babcock & Wilcox Ltd. (£108,292); for the shunt compensating reactors to C. A. Parsons & Co. Ltd. (£191,920).

The dam across the Zambesi will be of the concrete arch type and will be 400 ft. high and about 1,800 ft. long at crest level. It will create a lake 230 miles in length and having a surface area of about 1,600 sq. miles. There is every expectation that the initial block of power will be available in 1960. The consulting engineers for the civil work are Gibb, Coyne, Sogei (Kariba) (Pvt) Ltd, and the mechanical and electrical work will be supervised by Messrs. Merz and McLellan.

Brownlee Dam Model

BROWNLEE DAM has been built in miniature in the hydraulic laboratory at Washington State College in order to establish design characteristics on what is to be one of the world's highest earthfill dams. Idaho Power Company last year was granted a licence by the Federal Power Commission to build the dam, which is scheduled to be the first in a series of three authorised by the same licence in Hells Canyon of Snake River. Brownlee is to be located farthest upstream, next downstream is to be Oxbow dam, and below it will be the Hells Canyon dam. The $63,000,000 Brownlee project will have a capacity of 540 MW. It will provide a million and a half acre feet of storage of which a million acre feet will be used for flood control. The dam will have a crest length of 1,380 ft. and will rise 395 ft. above the river bed.

The model was constructed to a scale of one to seventy and has a river bed 55 ft. long and represents a section of the river more than three-quarters of a mile in length. The model dam stretches 25 ft. across the little river bed and its basin stands 6 ft. high. Studies are now in progress on Brownlee's flip bucket design.

Brownlee is the fourth full-scale working dam model built at WSC within the past two years. The laboratory started originally with the Noxon Rapids dam, now under construction on the Clark Fork River for the

Washington Water Power Company. Later, a working model of the Northwest Power Company's Pleasant Valley dam was constructed, and a spillway section was constructed of the Grant County PUD's Priest Rapids Dam.

Progress at Ohakuri

A CONTRACT for the construction of the diversion tunnel at the Ohakuri hydro-electric station site on the Waikato River has been let to the Fletcher Construction Co., Ltd. The Ohakuri project, which is the seventh of ten such projects on the Waikato River in New Zealand's North Island, will have a 1,400 ft. concrete-lined diversion tunnel driven through solidified breccia to a diameter of 25 ft. A shaft will be built and a gate installed to shut off the flow in the tunnel after the dam is built. At the wide dam sites at Whakamaru and Atiamuri it was possible to divert the river by an open cut, but at Ohakuri, as at Maraetai, the site is narrow and a tunnel is needed to take the full flow of the river while the dam is being built. The Ministry of Works organisation at Mangakino will supervise the construction of the tunnel. It will also construct most of the balance of the project. Its forces are at present fully engaged at Atiamuri and Waipapa and the letting of the Ohakuri tunnel contract was necessary in order to keep up to the programme for developing the full power resources of the river.

The 150 ft. earth dam with two lower concrete wings planned for the Ohakuri scheme will be one of the highest earth dams in New Zealand. It will have a base width of at least 600 ft. and will impound the largest lake in the Waikato chain—stretching back over more than 30 miles and submerging the lower reaches of the Orakei-Koraka thermal area. It will provide a head of over 100 ft. Ohakuri has been delayed by lengthy investigations which have not yet been fully completed. The decision to use an earth dam was made after it was found that the foundation rock had soft pockets and a low elastic modulus. Three penstocks will take the lake water to a power house of 84 MW capacity. The first two of the three generating units are due to be in use by April, 1961, the third six months later.

Clearing nearby exotic forests and forming good access roads to the narrow gorge where the dam is to be built have been the major jobs to date. A new, semi-permanent village at Atiamuri will be the dormitory town for the men working on the Ohakuri scheme. Construction will be intensified as the Whakamaru project rapidly winds up and heavy machines and their drivers and rock workers are to be switched to the new scheme. Once again the building of a big power scheme will also spell better road access to farm development areas. The new road into the dam site will run in almost a straight line from the new bridge over the Waikato River at Atiamuri, cutting the distance as well as improving the running for heavy vehicles. The road will cross the top of the Ohakuri earth dam and link up with a country road which runs out at the Upper Atiamuri school. Access to an area well up the lake is also to be provided by a link between the Atiamuri-Taupo and Rotorua-Taupo highways. This will run from the south at Tutukau Road and cross the Ohakuri lake some distance upstream of Orakei Korako.

At Atiamuri, where the first machines are expected to come into operation in the winter of 1959, work is going ahead on the dam foundations and the diversion channel. The opening up of the Waipapa site is well up to schedule and excavation of the diversion channel has begun. Power is expected from Ohakuri and Waipapa by the winter of 1961. These three new projects will add approximately 200 MW to the 750 MW already being generated in the North Island. The latter figure includes Khakamaru and the fuel stations at King's Wharf and Evans Bay. The Government is also going ahead with the construction of a steam station at Mercer and with the geothermal steam project at Wairakei.

Hamilton River Survey

IN a paper read recently before The Engineering Institute of Canada, Messrs. G. V. Eckenfelder, W. P. Harland and E. N. Webb gave a fascinating account of a preliminary survey of the Hamilton River catchment carried out during 1954 and 1955 by British Newfoundland Corporation. Considering the remoteness of the region and the rigorous climatic and other conditions, an amazing amount of work was accomplished in the limited time available. Aerial surveying, assisted by the essential minimum of ground work, formed the basis of the campaign, but valuable work was also done on the seismic sounding of possible structure sites, soil investigations, underwater soundings by echo and direct methods, and in stream gauging. A highly practicable transmission route has been defined from Grand Falls to Seven Islands, where development of an industrial centre would constitute one of several possible outlets for the potential power, and a feasible route for an access road to the construction site has been surveyed.

The purpose of this work has been to confirm earlier feasibility reports and to obtain pre-design data. No commitment has yet been made with regard to construction other than that of the pioneer access road. The capacity of Grand Falls is estimated at not less than three million continuous horsepower, with a further two million below the Falls.

Project for Madras

ON June 29, Mr. C. D. Deshmukh, India's Finance Minister, inaugurated the Rs.35-crore Kundah hydro-electric project in the Nilgiris in Madras State. Canada has agreed to assist in the completion of the project by providing a financial contribution of $20 million. An agreement to this effect under the Colombo Plan between the Governments of Canada and India is shortly to be signed in New Delhi. The project is situated on the Kundah river, and Canada's contribution will include turbines, generators and other power-house equipment, substation and transmission equipment for transmission lines and materials and construction equipment for civil works. Canada will also supply construction engineers to supervise certain aspects of the work. The first phase of the project is already well advanced and will be completed by the end of this year. It will comprise three dams on the Emerald Avalanche and the Upper Bhavani rivers and two power stations on the Kundah river. This will add about 145,000 kW to Madras State's available electricity resources. India will build

all civil works, supply labour and local materials and will be responsible for housing, roads and other facilities.

Water Power in the Irish Republic

THE Annual Report of the Irish Electricity Supply Board for the year ended March 31, 1956, states that with the exception of 1933-34 and 1952-53, the year was the driest since the establishment of the Shannon scheme and that only 487 million kWh were generated in the hydro stations as compared with 590 million kWh in a year of average rainfall.

Excellent progress was being maintained on the Inniscara and Carrigadrohid stations of the river Lee, and it is hoped to have both stations in commission before the end of 1957, adding 27 MW to the country's capacity. Progress was also being maintained on the 4 MW Clady scheme in Co. Donegal, which should be placed in operation in 1958. The dredging and ancillary operations in connection with the Erne development were expected to be completed during the present summer.

Revised proposals embodying a pump-storage project at the Torc Waterfall, Co. Kerry, were under consideration, and the economics of the development of the Ballisodare river, Co. Sligo, were under review. Investigations on the river Flesk, Co. Kerry, showed that development would be uneconomic. Collection of data was being continued on 17 other rivers.

A Name for Rapide Sans Nom

THE site of The Shawinigan Water and Power Company's newest hydro-electric development, Rapide Sans Nom or the rapid without a name, has been named Rapide Beaumont by the Quebec Geographical Commission. It is on the St. Maurice River about 10 miles above La Tuque. Announcement of the naming of the rapids after Robert J. Beaumont, chairman of the Board of Directors of the Shawinigan Company, was made in a recent directive by the Commission. Immediately following the Provincial Government's move, J. A. Fuller, president of The Shawinigan Water and Power Company, announced that the new hydro-electric plant at the site, construction of which has started, would now be known as the Beaumont development. The plant will have an ultimate capacity of 246,200 kW and first power is scheduled to be produced late in 1958. It is expected to cost about $56,000,000, including an additional transmission line to Trois-Rivières.

Correspondence

Evaporation from a Free Water Surface

To the Editor of WATER POWER

In your editorial in the issue for May 1956 you make the statement that "Lake Mead above Hoover Dam is likely to be useless for power generation in about 200 years' time." In the interest of correcting an apparently widespread impression I would like to draw your attention to U.S. Geological Survey Circular 346, "First Fourteen Years of Lake Mead," in which it is pointed out (Fig. 9) that the usefulness of the reservoir will not be materially impaired before the year 2100 and perhaps not until after 2400 and thus the time at which it will become useless for power generation would be still further in the future than these dates.

I also noted with interest the article by N. J. Cochrane in the May 1956 issue of WATER POWER. Mr. Cochrane adds another empirical formula to the many already proposed for determining evaporation from a free water surface. It is not clear how Mr. Cochrane deduces that his is a "logical formula." Although his formula may not include any "variable constants" to which he objects so strongly, the constants or coefficients he does use must have rather peculiar dimensions.

Among Mr. Cochrane's comments on the Lake Hefner studies he states "Nevertheless, some care must be taken in abstracting the results as some of the data have been 'adjusted.'" This statement appears to stigmatise these data. Extreme care was taken in the reports of the Lake Hefner experiment to publish the original observations and these are clearly given in every case and are set forth in detail in a separate 300-page volume on base data. We are not sure of the adjustments to which Mr. Cochrane refers.

In addition, the technical report shows results that include the effect of the thermal expansion of the lake, obviously a necessary procedure, and also lists Class-A pan evaporation data that were adjusted for known errors of observation. In drawing attention of a user of the technical report to the existence of more than one set of data, the impression may be left in the minds of many readers that the original or "unadjusted" data were not presented.

G. EARL HARBECK, JR.
Staff Engineer,
Geological Survey,
U.S. Department of the Interior.

Mr. Cochrane replies as follows:— The Lake Hefner experiment was the best of its kind so far and Mr. Harbeck and his colleagues are to be congratulated on publishing so much invaluable information. However, neither the experiment nor the author's formula would have been necessary if a scientifically exact method existed for calculating evaporation from large bodies of water. The climatic increments used in the author's formula are the only ones likely to be available in the primitive areas of the world in which he is concerned. The author suggests it is clear from the reading of Volume I of the Lake Hefner Report that a significant proportion of the Water Budget Data was adjusted for what seemed good reasons to the experimenters, apart from temperature corrections. On page 141, if the dates are inclusive, there were apparently adjustments on 43 days, while the Report itself says that comparison with the adjusted monthly lake evaporation values with the observed water-budget amounts shows substantial differences for individual months, although the sixteen-month totals agree reasonably well. If this is not the meaning intended in the Report, then the author will be pleased to withdraw his comments.

N. J. COCHRANE.

Fig. 1. Lilledal, showing Dalen III, bottom centre, and new construction road, left

The Aura Development

Aura power station has a capacity of about 300 MW and is the largest single power plant in Norway. It also contains Norway's largest generating sets. The power is being used partly to supply an aluminium works at Sunndalsora, partly for local supply, and partly for bulk supply to the surrounding districts

PART ONE

THE Aura power station of Norges Vassdrags-og Elektrisitetsvesen (Norwegian Watercourse and Electricity Board), which has only recently been completed, has a capacity of about 300 MW and is the largest single development in Norway. It is a high-head scheme operating under a total head of 780 m., and will comprise seven horizontal Pelton-wheel generating sets, four rated at 37·5 MVA and three at 62·5 MVA, the actual output of the units having been measured at 32 and 60 MW each. The latter machines are the largest generating sets in Norway.

The station is located in the "fylke" (or "county") of Møre og Romsdal in Central Norway, and is built in the mountainside at the head of Sunndalsfjord, which is about 45 km. long and reaches the west coast at Kristiansund. It utilises the waters of the Lilledalselv, which discharges into Sunndalsfjord, and of the Aura, which flows through Lillevann and Eikisdalsvann into Langfjord, an arm of Romsdalsfjord, lying south-west of Sunndalsfjord.

Roughly half the capacity of the station will be used to supply an aluminium works which has been built at Sunndalsøra on the delta at the head of Sunndalsfjord. The remainder will provide power for local supply and for bulk supply to Møre og Romsdal and to the adjacent fylke of Trondelag lying immediately to the north-east.

Although the Aura development is now fully completed and operating, it has had a long and somewhat chequered history. As long ago as 1913 a concession was granted to a private company, A/S Aura, mainly with English capital, to build separate stations

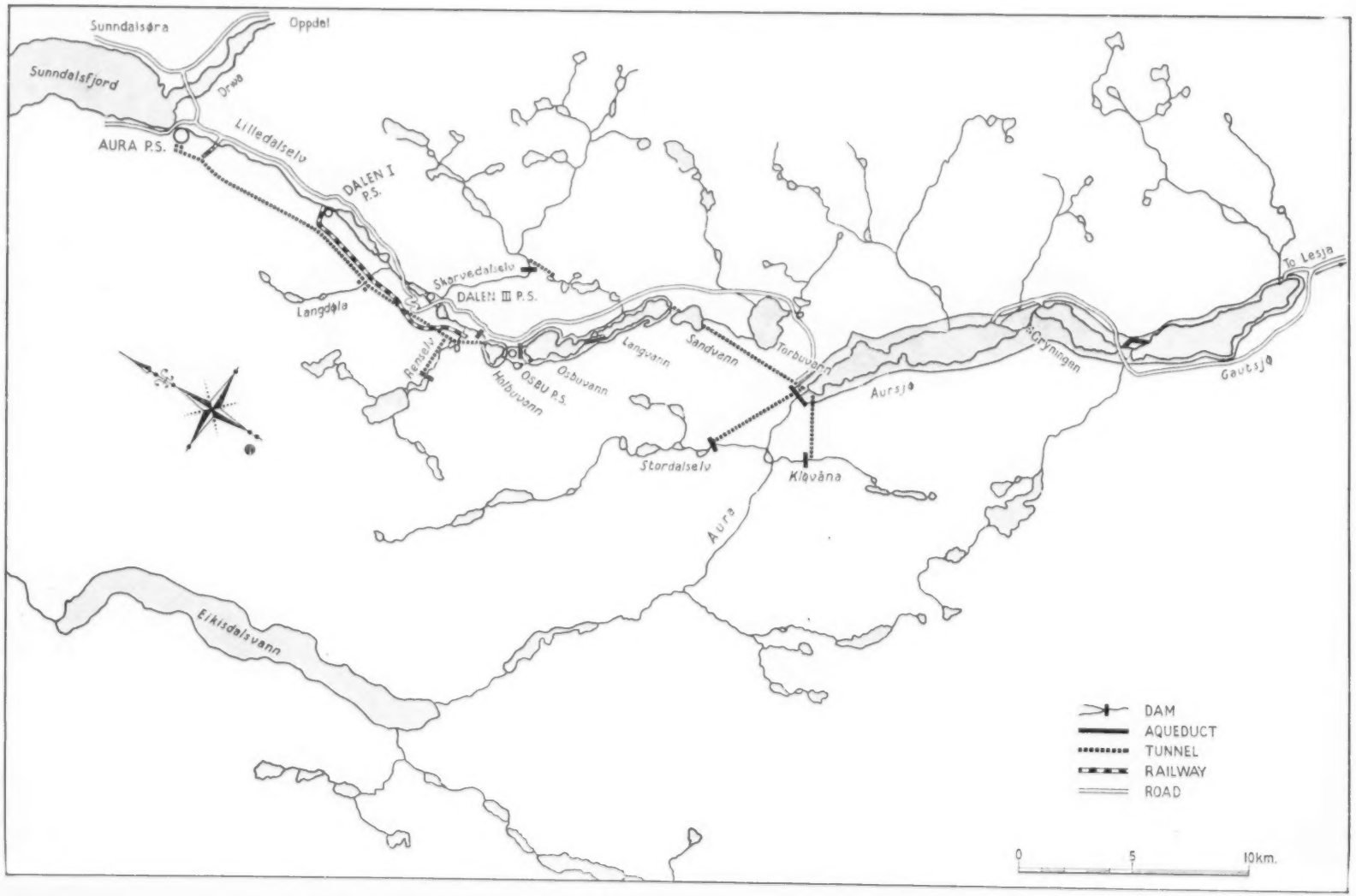


Fig. 2. Map of the catchment area, comprising the Lilledal and Aura drainages

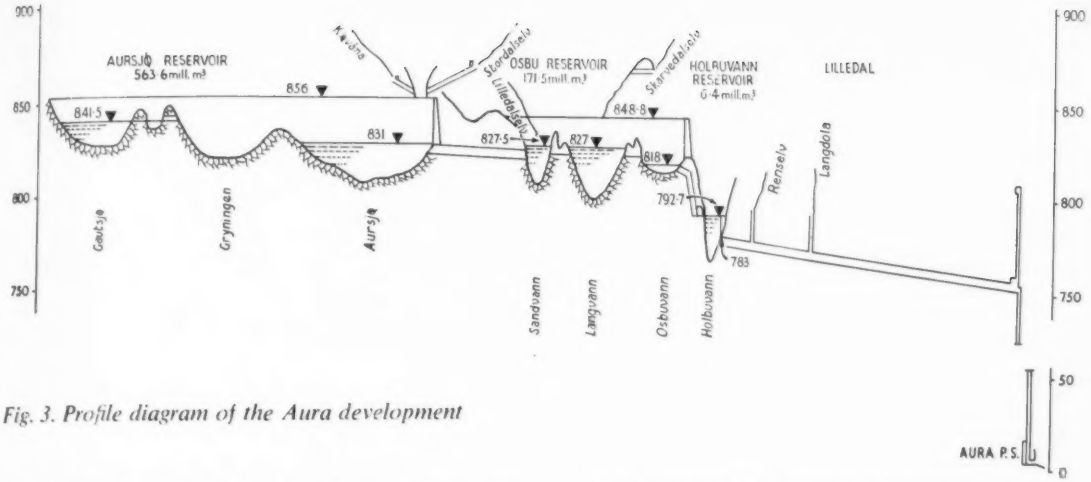


Fig. 3. Profile diagram of the Aura development

on the Lilledalselv in Sunndal and on the Aura and the Mardøla in Eikisdal. Proposals were made at that time for a combined development but were not sanctioned. The first stage contemplated by A/S Aura was to build a 70 MW station on the Lilledalselv to supply carbide and cyanamid works to be erected at Sunndalsøra, and work was begun at once with a force of 2,000 men and continued until the outbreak of war in 1914. After a short break it was continued until the autumn of 1919, when work ceased.

In 1927 A/S Aura applied for a concession for the combined development of the Lilledalselv and the Aura. This was granted in 1931, but the company did not find it expedient to proceed because they were not assured of the load.

Under the German occupation work was resumed in 1942 by a German-controlled company, A/S Nordag, which took over the properties with a view to supplying a works for the production of light metals to be established at Sunndalsøra, but it ceased in 1943.

After the war the properties of A/S Nordag were taken over by the Directorate for Enemy Estates and transferred to the Watercourse Board, whereupon in 1947 the Storting (the Norwegian Parliament) granted capital to proceed with the development on the basis of a first construction stage of two units totalling 60 MW. In 1951 a further Storting resolution gave effect to the establishment of an aluminium works at Sunndalsøra and to the completion of the development with seven units, thus bringing the scheme for the main Aura plant into its present form.

Furthermore, in 1955 means were also granted for a new plant at Osbu above the intake for the main Aura plant. Osbu, with one 23 MW unit, is expected to be commissioned in 1957.

The Catchment Area

As already stated, Aura power station utilises the waters from two catchments—those of the Lilledalselv and of the Aura. This forms an ideal combination, as the somewhat indifferent regulation obtainable in the Lilledal drainage is fully compensated by the excellent storage and regulation facilities afforded by the Aura system.

A map of the area, showing the locations of the dams, canals, tunnels and power stations, appears in Fig. 2, and a profile diagram of the scheme in Fig 3.

The high-level lakes forming the headwaters of the Lilledalselv, reading from upstream, are Torbuvann, Sandvann, Langvann, Osbuvann, and Holbuvann. From Holbuvann the flow falls in a cataract into Lilledal, where it passes successively through three lakes before discharging into Sunndalsfjord. Three tributaries flow into the river during its passage through Lilledal—the Renselv from the west, the Skarvedalselv from the east, and the Langdøla from the west.

All the lakes in this catchment are small, and the cost of individual regulation would be high, so the cheapest method of storage has been found to consist of building a tunnel from Sandvann to Langvann, a canal from Langvann to Osbuvann, and a regulating dam at the foot of Osbuvann, thus raising all three lakes to a common level. Torbuvann, which lies at 849·2 m., discharges naturally to Sandvann. Osbu lake at 825·8 m. has been drained by a tunnel to 818 m. and raised by a provisional dam, constructed during the war, to 828·8. A new dam, raising the water level to 848·8 m., is now under construction in conjunction with the new Osbu power plant to utilise the head between Osbu and Holbu lakes. The regulated discharge from Osbuvann flows to Holbuvann, which is dammed to a level of 792·7 m. and forms the supply-tunnel intake basin for the main Aura plant.

Of the three tributaries mentioned above, Skarvedalselv on the east has been dammed and the headwaters diverted through a tunnel to a tributary discharging into Langvann. The Renselv and the Langdøla are brought into the supply tunnel through side intakes.

In the initial stage—40 years ago—a temporary station of 1·5 MW capacity, known as Dalen I, was built downstream of the lakes in Lilledal, and supplied power to Sunndalsøra. When the final scheme was put in hand, a 4 MW construction station, Dalen III, was built at the head of Lilledal. With the river diverted to the intake of the main plant as just described, Dalen III will receive very little water and will go out of commission. The units are now to be moved to the huge Tokke scheme in Southern Norway. A view in Lilledal, showing Dalen III, appears in Fig. 1.

In the Aura catchment the headwaters are derived from three large lakes, Gautsjø, Gryningen and Aursjø (see Fig. 2). By making a cut between Gautsjø and Gryningen and by damming the outlet from Aursjø

Fig. 4. A view of Aursjø in the early stages of impounding

these three lakes are being converted into a single reservoir standing at a level of 856·0 m. and providing a storage of 563·6 million cu. m. down to a level of 831·0 m. With reduced draw-off, Aursjø can be lowered to 829·7 m., giving some further storage.

Downstream of Aursjø two tributaries flow into the Aura, the Stordalselv from the north and the Klovåna from the south. The headwaters of both of these tributaries are being diverted to the main reservoir by dams and tunnels.

All the waters from the Aura storage are transferred to the Lilledal system through a diversion tunnel from Aursjø to Sandvann, where they mingle with the Lilledal headwaters flowing through to Osbu and Holbuvann and the supply tunnel.

The Lilledal catchment area, including that of the impounded tributaries, is 289 sq. km. and the average annual flow, based on records extending over a number of years, is 12 cu. m. per sec. The corresponding figures for the Aura catchment are 567 sq. km. and 16 cu. m. per sec., giving a total area of 856 sq. km. and a total average annual flow of 28 cu. m. per sec. On account of the good regulation obtainable, a regulated flow of 24·5 cu. m. per sec. will be obtainable even in adverse years, producing 1,530 million kWh per annum in the two power plants. When all machines are on full load they will require a flow of 43 cu. m. per sec., so that in an average or wet year a higher production can be obtained. At Aursjø dam the calculated maximum flood will be 280 cu. m. per sec. with 0·8 m. of self regulation. At Osbu dam the corresponding figures are 150 cu. m. per sec. with 0·5 m. of self regulation.

Aursjo Dam

Aursjø dam is 900 m. downstream of the natural outlet of the lake, and is 970 m. long, with a maximum height of 37·5 m. Beyond the southern extremity of the dam a spillway, 165 m. wide, has been cut in the mountainside.

The dam itself is of the rockfill type, and as will be seen from the section, Fig. 6, a somewhat unusual design has been adopted to suit the materials available. Ideally, a self-sealing earthfill construction would have been most to be desired, but suitable impervious and semi-pervious fill was so far from the site that such a construction would have been uneconomic. On the other hand, rockfill was available in abundance in the form of spoil from the tunnels supplemented by quarried rock. The impervious layer is located on the water face of the dam and takes the form of a concrete membrane backed by stone pitching and faced with timber.

Referring again to Fig. 6, a permanent concrete cofferdam was built across the deepest part of the valley, and forms the upstream toe of the main dam. Behind this cofferdam a footing for the stone pitching was built of stone blocks set in cement mortar. The rockfill, which was handled by Euclid trucks, was dropped from a fair height so as to knock sharp corners off the large boulders, which in turn crushed and compacted the smaller material, the whole mass being finally compacted by water jets. It was reckoned that by the time the impervious membrane was added practically all settlement would have taken place.

The stone pitching was set by cranes, and ranged from 3 m. thick at the bottom of the face to 2 m. at the top. Reinforced-concrete beams were set in the pitching to register with the contraction joints in the concrete membrane, which consists of lightly reinforced concrete panels 12 m. square by 0·5 m. thick. Finally the concrete was faced with a double lining of timber.

As will be noted from the cross section, the slope of the impervious membrane decreases progressively from 1 : 1·38 at the bottom to 1 : 1 at the top, so that the membrane presents a concave face to the water. This has been done in order to form a slight inverted arch which would resist any buckling tendency. By placing the impervious membrane on the water face the seepage line in the rockfill is kept low, and a further advantage, to which importance was attached, is

Fig. 5. Aursjø dam under construction, showing the concrete membrane being brought up over the stone pitching. To the left of the dam a gangway has been built over the concrete cofferdam, and on the extreme left is the construction for the intake to Sandvann

the easy accessibility for inspection and maintenance of the membrane.

Fig. 5 is a view of the dam taken at a particularly interesting stage of construction, shortly after we visited the site. Here the dam has not yet been brought up to height, but the stone pitching can be seen covering most of the water face, and the concrete membrane is in course of construction on the lower part of the face. To the left of this membrane can be seen the gangway extending along the top of the permanent concrete cofferdam.

The total amount of material in the finished dam is 800,000 cu. m. of rock and 17,500 cu. m. of concrete.

From Aursjø the water is conveyed to Sandvann through a tunnel 5 km. long and having a cross section of 32 sq. m. It was driven with the aid of American heavy mucking equipment and Euclid dumpers (see Fig. 8).

Osbu and Holbu Dams

A temporary timber dam was built at Osbu during the war, raising the water level to 829·8 m., and up to the present this dam has been in use, but a rockfill dam, similar in general design to that at Aursjø, is now being built, raising the level to 848·8 m. and providing a live storage of 171·5 million cu. m.

At Holbu a temporary concrete dam was built during the war to raise the water level from 776 to 782 m., but when we visited the site a permanent mass-concrete gravity dam was in an advanced stage of construction. This dam, which is now completed, raises the level to 792·7 m. and provides a storage of 6·4 million cu. m. It is about 350 m. long, and as will be seen from the plan, Fig. 10, has been constructed in three sections to suit the exigencies of the site, the right-hand section, 72 m. long, forming the spillway. With a drawdown to 782 m. a load at least 212 MW is still possible. With a lower intake level the load would have to be reduced. As explained previously, Holbu forms the intake basin for the main plant and the disposition of the tunnel intake and gate shaft will also be noted from the drawing. Entry of silt and debris into the tunnel is guarded against by a vertical baffle wall facing the tunnel mouth and carrying a trashrack through which the water has to descend to enter the tunnel. Protecting the entire intake structure is a further three-legged baffle wall in the path of any silt moving towards the intake from the original stream bed, and the space between this baffle wall and the intake can be cleared of any accumulation by a scour sluice set in the dam at this point.

The intake gate is of the segment type, 4 × 5·5 m. in dimensions.

Transport of materials and supplies was greatly facilitated by a railway that had been built 40

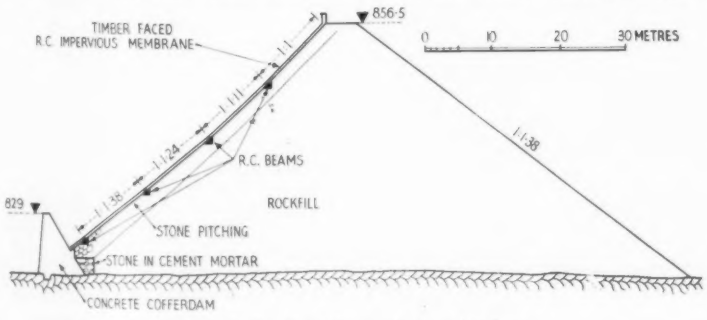


Fig. 6. Section through Aursjø dam

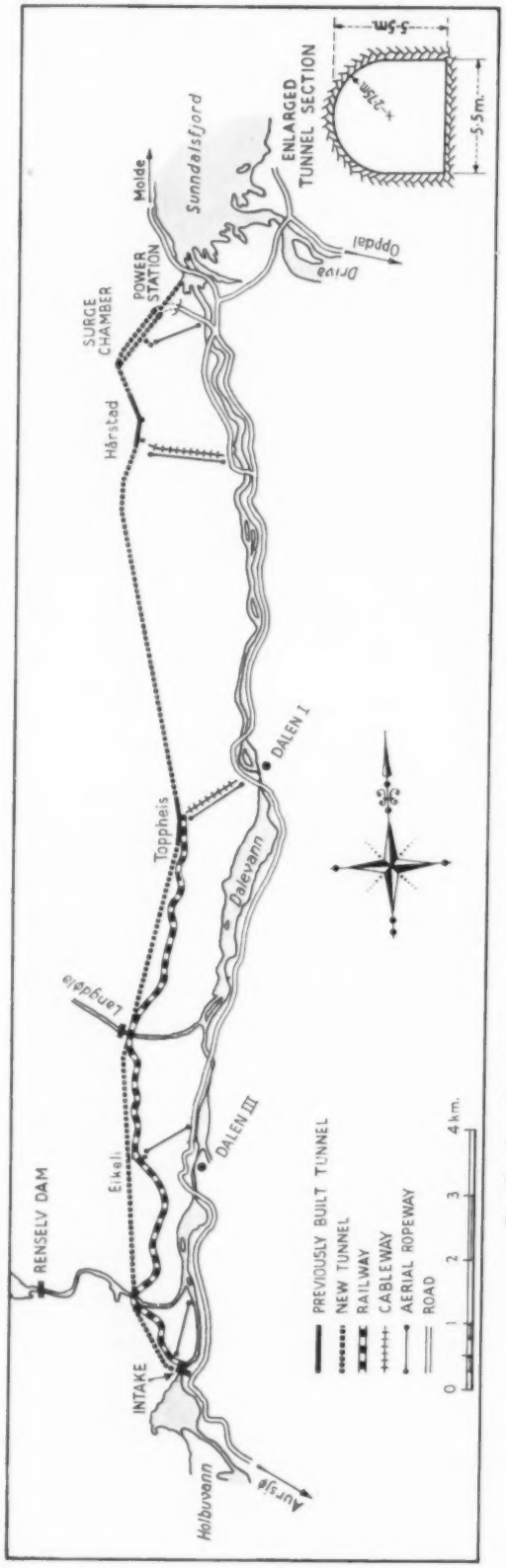


Fig. 7. Map showing the route of the supply tunnel from Holbuvann to Aura power station

years ago along the mountainside in Lilledal at about the level of the supply tunnel and terminated near the dam site, connection to the railway from Lilledal being effected by a rope railway. The railway route is indicated in the map, Fig. 2, and is shown in greater detail in Fig. 7. However, the railway did not have sufficient transport capacity and usually could not be opened before June because of snow; furthermore, for later operation of the system it was found to be rather expensive. A new road was therefore constructed up the valley and was carried as far as Aursjø. It was thus possible to dispense with the railroad as soon as it was no longer needed for transport to the tunnel adits.

Aggregate for the dam was prepared from the spoil from the tunnel, and sand was obtained from the river bed about 12 km. away. In the winter, warm water for concrete mixing was derived from the boiler of an old railway engine from the railway just mentioned. Concrete was prepared in a plant located immediately behind the dam and was loaded into bottom-emptying trucks which were elevated to a wooden bridge extending along the dam and carried on trestles on the upstream and downstream sides. On reaching the block to be concreted, each truck dropped its charge through an aperature in the floor of the bridge into a telescopic tube which could be swung to guide the concrete to the point desired. The bridge section, placing tubes, shuttering and so forth, were all made demountable so that they could be re-erected in different places as the work progressed. The blocks forming the dam were mostly 6 and 8 m. wide, and the concrete was placed in half-metre lifts.

Supply Tunnel, Surge Chamber and Penstock Tunnels

The supply tunnel is 15·9 km. long and 27 sq. m. in cross section, the fall from intake to surge chamber being 23 m. It is lined for a total length of about 900 m.

In 1913, when the development of the Lilledal catchment only was envisaged, the tunnel was planned to be 17·9 km. long and to be driven to a section of 14 sq. m. from 16 adits, and in 1914 work was begun from eight adits, about 2,500 m. of tunnel being driven.

In 1948, with the revision of the scheme to include the Aura catchment, the design was changed to that actually adopted, and plans were drawn up for construction from four adits, a fifth being used for ventilation. All of these adits were reached by aerial ropeways, as indicated in Fig. 7, and two of them were also served by funicular railways.

Initially the drilling equipment used was transferred from the Mår scheme, which had just been completed, but this was replaced as soon as possible by new Atlas RH-656W and RH-656-2W drills fitted with BMK61A2 pushers. About 15,000 Sandvik Coromant steels were supplied per annum. The rock was gneiss, and a net drilling rate of 0·4 m. (16 in.) per min. was achieved.

Six drillers were employed on each face, four working from the floor and two from a jumbo. The holes were drilled on the fan-cut method, 50-60 holes being drilled per round, corresponding to a meterage of 130-140 m. (425-460 ft.). The advance per round was 2·4-2·8 m. (7·9-9·2 ft.). The maximum advance per working week was 54 m. (177 ft.), the average advance 40-50 m. (130-165 ft.) and the overall average, includ-

Fig. 8. At work in the Holbuvann-Aura supply tunnel

Fig. 9. Penstock A in course of erection

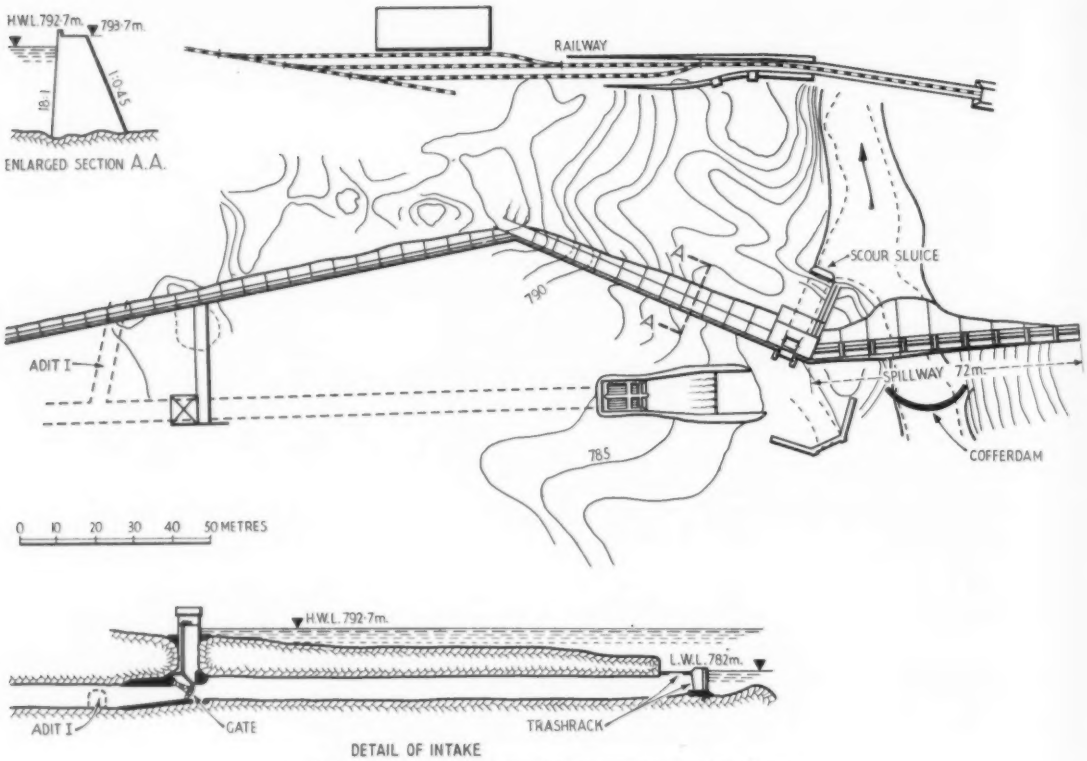


Fig. 10. Plan of Holbu mass concrete gravity dam

ing holidays, was 30 m. (97 ft.). The consumption of explosive was 1·2 kg. per cu. m. (2·02 lb. per cu. yard). Mucking was accomplished by Eimco loaders.

The power station has two machine halls, known as the north hall and the south hall, the north hall containing four 32 MW sets (Nos. 4 to 7) and the south hall three 60 MW sets (Nos. 1 to 3). To serve these two halls the supply tunnel bifurcates at the surge chamber into two concrete-lined circular branches, each controlled by a 2·5 × 4·5 m. gate. Each branch has its own lower surge chamber for negative surges, but the two branches share a common upper chamber for positive surges.

A debris sump is formed in each branch downstream of the gate, after which each branch divides into two pipes leading to a valve chamber, where an automatic and a hand-operated Kværner Brug valve are provided for each pipe. From these valve chambers separate penstock tunnels, each carrying two penstocks, lead respectively to the north and the south machine halls. Each tunnel is 1,100 m. long and has a section of 35 sq. m. and a gradient of 45 deg.

These tunnels were driven from the bottom and from an adit about half-way up. Two pilot headings, each 2 m. square, were driven side by side along the line of each tunnel, which was then opened out from the top, one heading being used for access and the other for dropping the spoil. The fall of rock fragments on to the penstocks is guarded against by wire netting secured to the roof by roofbolts, and for short distances the roof is lined.

Penstocks

The chequered history of the Aura scheme has been reflected to some extent in that of the penstocks, for the pipes for the two penstocks for the north hall were originally purchased from Ferrum Montage A/S during the war for a projected station at Tyssefallene. Work on that station was not proceeded with, and the pipes were adapted for use at Aura, in workshops built specially for the purpose. To withstand the required head new bottom sections were supplied by Ets. Bouchayer et Viallet, Grenoble, who also supervised the erection, which was carried out by Ferrum Montage A/S. The bifurcation at the bottom of penstock A, which supplies turbines Nos. 4 and 5, is made by a Bouchayer spherical Y-piece, and that at the bottom of penstock B, supplying turbines Nos. 6 and 7, by a Sulzer Y-piece. The topmost portion of penstock B has been built from pipes supplied by the Mannesmann Tube Company, Dusseldorf.

Each penstock has an internal diameter of 1·9 m. at the upstream end tapering to 1·4 m. at the downstream end.

Between the two penstocks is a rail track carrying a permanent erection and inspection trolley hauled by an electric winch at the top of the tunnel. A view of penstock A in course of erection is given in Fig. 9.

In the tunnel leading to the south hall, penstock C serves turbines Nos. 1 and 2, and has diameters ranging from 2·2 to 1·8 m. The upper portion of this penstock was supplied by Voest, of Linz in Austria, and the remainder by Ets. Bouchayer et Viallet. Penstock D, which was supplied throughout by Voest, serves turbine No. 3 only, and has diameters ranging from 1·6 to 1·2 m. Both penstocks were erected by Ferrum Montage A/S.

(To be continued)

The World Power Conference 1956

In this first article of our series reviewing the Vienna Conference we discuss the survey of national power resources and summarise two important contributions on the water power resources of Russia and of China respectively

PART ONE

THE World Power Conference took place in Vienna in June of this year, in the presence of over 2,000 distinguished engineers and scientists from practically every country in the world. The President was Sir Harold Hartley, of Great Britain, and at the end of the conference he handed over the presidency to Mr. Franz Holzinger, the distinguished Austrian engineer, who has been closely associated with Austrian power economy. The pattern of the conference followed that set for its predecessors, and it included first a section which included surveys of the development of national power economies from 1950 to 1954, and then other sections relating to the method of compilation and use of statistics in the production and utilisation of energy. After this general survey of the world position in regard to all sources of energy, the proceedings became divided into specialist sections, such as those relating to solid fuels and their preparation, oil fuels, thermal power stations, hydro-electric plant and atomic energy. We are here concerned principally with the two sections first mentioned and with the hydro-electric papers.

National Power Resources

The general report of Section A, in which the development of national power economies was surveyed, dealt with 38 papers sent in from 26 countries, with the addition of a valuable paper from the USSR on that country's water-power resources, sent in too late to be included in the report.

Electricity, in relation to other sources of energy, is still a very small proportion of the total energy consumed, measured at the point of consumption. Electricity from thermal and hydro stations was seen to account for only 9·1% of the world's useful energy consumption, compared with 35·1% from coal and coke, 23·7% from oil products, 23·3% from natural and other gas, and 8·8% from firewood and peat. On the other hand, the rate of increase of consumption of electrical energy is much greater than that of the overall increase in energy consumption. Over 8% more electricity has been used each year since 1950, whereas the corresponding cumulative annual rise in total energy consumption is 4·5%.

Analysing this usage of electrical energy, the general report claimed that although the development of water-power resources has continued energetically, their share of total electricity production has decreased. In Europe it dropped from 37% in 1950 to 36% in 1954. In the United States it decreased over the same period from 29% to 23%. The tendencies in hydro-electric development noticed by Dr. Bauer, of Austria, the general reporter, included the fact that projects for harnessing hydro power reflected an increasing tendency towards the construction of large-capacity storage reservoirs. In the construction of run-of-river plants he brought out the tendency which he had noticed in regard to continuous increase of installed capacity. All countries appeared to be engaged in an intensive investigation into their potential hydro-electric resources. More and more projects are designed as multi-purpose schemes, serving for electricity production as well as for one or more of the purposes of flood control, irrigation, water supply, drainage of marsh land, and navigation. The report shows that there is a general increase in the size of generators. The largest unit mentioned in the report is a 165,000 h.p. Francis turbine at Grand Coulee.

The conference papers showed clearly that the unequal distribution of natural resources, both of coal, oil and water power, has meant great increases in power transmission, and moreover political differences between Governments do not appear to prevent the power-supply authorities of neighbouring countries from reaching agreement for interchange of power on an ever-increasing scale, and for joint utilisation of catchment areas and rivers. A paragraph from the general report may here be quoted in full:—

"The situation in several countries is already marked by the imminent exhaustion of economic resources for further hydro-electric development. Countries in which all rivers are governed by similar hydrographical conditions, and which, therefore, are incapable of equalising annual water-power supplies by a system of electrical interconnection, must resort to the construction of big storage plants, if deficient in other exploitable sources of energy. The same applies to countries with rivers running dry during the rainless season. A desire for independence of imported fuel for the production of electricity has led to the construction of excessively large storage plants, designed to meet all possible load-demand requirements. Pumped storage has gained increasingly in importance, to equalise both daily and seasonal fluctuations in demand."

Construction of New Hydro Plants

The general reporter said that in general costs for the construction of new hydro power plants have gone up considerably, since the most economically advantageous projects have already been completed. Taking into account that the calculation of current prices for electric power in most countries is still based on the relatively low capital interest rate on existing power plants, an increase in prices, at present artificially kept low in some countries by Government policy, appears almost inevitable. Nevertheless, he pointed out that in all countries the price of electricity has risen considerably less than the cost-of-living index.

Another paragraph is also worthy of quotation in full. Dr. Bauer said:—

"A vital question is how long will it still be economical to construct conventional-type power plants, or at what date will the rising costs of power generation by these plants exceed the falling costs of electric power production in nuclear-fission plants. Even countries mainly relying on hydro-electric power production expect that atomic energy plants will cover the base-load demand in the distant future (if necessary in conjunction with conventional thermal power plants), while hydro-electric energy will be employed to meet peak demand. In conclusion it may be said that conventional sources of energy will continue to be harnessed for new facilities of electricity production until the date when competition from atomic energy becomes critical. This date will differ from country to country."

It may be appropriate here to introduce some impressions gained by the writer from the discussions in the atomic-energy section, bearing on the points mentioned immediately above. Great Britain, due to her special fuel problems, is forging ahead rapidly with a large-scale programme of nuclear power development, whereas other countries are still a very long way behind in the race to use the power of the atom. The United States and the USSR both have major programmes of nuclear power development, but these centre on experimental reactor design rather than on bread-and-butter stations to carry a significant share of the country's energy production. Sweden, Norway, Holland, France, Italy and Canada all have larger or smaller nuclear power programmes, but it was freely admitted at the Vienna conference that a very long period will elapse before any country other than Great Britain will expect nuclear energy to take even as much as 1% of the burden of electricity supply. The emphasis at all times in the discussions on many aspects of the work of the conference always led to the clear conclusion that conventional sources of energy and particularly water power should be developed with undiminished vigour, and that there was no reason ever to think that existing hydro plants would become obsolete at any time in the future.

Water-Power Resources in Russia

It is, perhaps, appropriate here to introduce some extracts from the paper by Professor A. N. Vosnesensky, Director of the All-Union Organisation for Designing Hydro-electric Power Plants in the USSR. It has been possible, over recent years, to provide in these pages information about hydro-electric progress in very many countries of the world; but the World Power Conference provided the first occasion on which an authoritative statement on Russian progress in this field has been published. Professor Vosnesensky says that a new estimate of the water-power potential of the country was completed in 1950. Some 1,477 rivers were taken into account. Their theoretical gross potential energy was estimated at 340 million kW, or 2,978 billion kWh per annum. The method used to determine the theoretical gross potential was to apply the formula $P = 9{\cdot}81\ QH$ kW, or $E = 85{,}936\ QH$ kWh, where Q is the arithmetical average of mean long-term utility flow, the flow being given in cubic metres per second at terminal points of the section of watercourse under consideration. This latter figure was determined either on the basis of direct data gathered over a number of years or on the basis of readings gathered over a short period of time and theoretically interpolated into the long-term data. H is the gross head in metres, i.e. the difference in level between the terminal points of the section when viewed longitudinally. The paper goes on to say that further estimates made since the 1950 survey have increased the probable theoretical gross water-power potential in the USSR to 420 million kW, or 3,680 billion kWh.

The water-power potential of the European and Asiatic territories of the USSR is given in the accompanying table. It was expected that about 50% of the theoretical gross water-power potential would be technically exploitable. The remaining 50% would be lost because the gross head could not be fully used due to backing up, losses in headraces, penstocks, and so on, and the insufficient regulating capacity of storage basins. Other causes of loss were the use of water for irrigating purposes and other needs, while the upper sections of rivers could not always be fully exploited.

WATER-POWER POTENTIAL OF USSR AND ASIA

Method of Estimate	Territory	Water-power Potential			
		million kW	billion kWh	%	thousand kWh per sq. km.
Probable theoretical gross potential (approximate estimate)	USSR	420	3,680	—	—
Theoretical gross potential (taking into account 1,477 rivers)	USSR	340	2,978	100	133·7
	Europe and the Caucasus	60	528	17·7	104·6
	Asia	280	2,450	82·3	143·0

It is interesting to read Professor Vosnesensky's viewpoint on the determination of the economic potential of water power, in view of the different economic structures which prevail in the USSR compared with those of other parts of the world. He says that the economic potential of exploiting water power depends on many factors. Some of them, such as terrain, are considered invariable even though their effect on the economics depends on the state of construction techniques. Even more important are variable factors such as the fuel balance and the cost of fuel, the size and structure of the power system in which the given station is operating, conditions of parallel operation with other hydro-electric stations, achievements in the field of long and extra-long-distance transmission, and finally load characteristics.

"Consequently, even though a great deal of attention is given to questions of economics in the construction of hydro-electric stations, we do not consider economic potential (as it is defined in E/ECE/ER/131) as a necessary category of account, and as one of the main characteristics of water-power resources. A regional economic characteristic of water-power resources is of

comparative value only when appraising the effectiveness of constructing hydro-electric stations in different regions of the country. Real objects for hydro-electric development from the total value of gross potential should be selected only on the basis of conscious planning over a long period. In doing so, the demands of the country as well as plans for the development of various regions and of different industries should be taken into account."

The document referred to by Professor Vosnesensky is, of course, one of the series produced by the Economic Commission for Europe, and one which has been recently reviewed in these columns.

The paper goes on to assess the proportion of the world's water-power resources belonging to the USSR, and the figure of 11·4% is stated as the Russian share in the world total. Thus, the author concludes:—

"The Soviet Union with 11·4% of the world's water power resources has the greatest possibilities for extensively constructing hydro-electric developments in all parts of its territory to quicken the growth of the national economy."

Professor Vosnesensky summarises the present state of utilisation of water power in the USSR by saying that the total capacity of hydro-electric stations belonging to the Ministry of Power Stations at the present time totals 5·5 million kW, and half of this capacity has been installed during the past five years. A considerable growth in hydro-electric capacity is expected in the current five-year period. Hydro-electric generation in 1960 will be raised to 59 billion kWh.

In the European part of the country, hydro-electric plant will be developed by systematically harnessing the water-power resources of the Volga, Kama, Dnieper, Dniester, Western Dvina, Neman and other rivers. During the sixth five-year plan the 2,100 MW Kuibishev station on the Volga will be complete, and also the Stalingrad station with a capacity of 2,300 MW. Construction work will start on the Saratov station, with a capacity of 1,000 MW, and also on the 800 MW Cheboxari station. On the river Kama construction work will be completed on the Votinsk station, with a capacity of 540 MW, and work will begin on the 900 MW lower Kama station. The total capacity of the lower Dnieper cascade will reach about 2,400 MW. There will be considerable hydro-electric development in the Caucasus, in Azerbaijan, Georgia and Armenia.

A characteristic feature of Russian hydro-electric development is the considerable intensification of water-power-plant construction in the eastern regions of the country, where the largest part of the water-power resources are concentrated. Large river flows, together with rock foundations enabling high dams to be constructed, and favourable conditions for regulation all contribute to the construction of highly efficient hydro-electric plants. The Angara and Enysei rivers are stated, by the author, to be exceptionally favourable for exploitation. On the Angara river hydro-electric stations soon to be constructed will have a total capacity of 10,000 MW, and an output of 70 billion kWh. This year the first station on the Angara will be commissioned at Irkutsk, where the capacity will be 650 MW. The dam at this plant will raise the level of lake Baikal, where an enormous storage basin will be formed, enabling the flow of water to all the other stations down the river to be regulated. At the present time, construction is under way on the enormous hydro-power plant at Bratsck, where the total capacity to be installed will be 3,200 MW.

The report goes on to mention even larger hydro stations which will be constructed on the Enysei river, with a total capacity of about 20,000 MW and an output of 130 billion kWh per annum. The sixth five-year period, which is about to commence, will see the construction of the Krasnojarsck station, again with a capacity of 3,200 MW. The construction of large hydro-electric plants is also in progress in Western Siberia, in particular on the river Ob. The Novosibirsck station on this river will have a capacity of 400 MW, and that at Kamensck station will provide 500 MW. The construction of large hydro-electric stations on the rivers of Siberia is a strong stimulus to the creation of a single Siberian power system to consolidate all the hydro stations on the Angara, Enysei and Ob rivers with the thermal stations in the Irkutsck-Cheremhovsck region, in the Kuzbass and elsewhere. The directives call for work to get under way in creating a consolidated power system for central Siberia from Novosibirsck to Irkutsck. Considerable hydro-electric development is also provided for in Central Asia and Kazakstan, in the Uzbek, Tadjik, Kirghiz and Kazakh Republics.

The author concludes by saying that hydro-electric development in the USSR serves many purposes. The hydro-electric stations are, as a rule, used for irrigation, navigation, flood control and other purposes in addition to power generating. For example, all the hydro-electric stations in Central Asia are also used to irrigate hundreds of thousands of square kilometres of dry and desert land. After the Volga and Lower Dnieper cascades are completed, these rivers will be turned into deep transit waterways, forming a single water system for the European part of the USSR. At the same time, immense possibilities will emerge in regard to the carrying out of irrigation work on the dry lands along the Volga, and in the Southern Ukraine. The planned principle of complex utilisation of hydro developments now being carried out considerably increases the general effect that harnessing the water-power resources of the country has on the national economy.

China's Power Resources

Another contribution not included in the list of papers presented to the World Power Conference, but added partly in manuscript and partly by verbal discussion was that which related to the Chinese development of electrical power generation. Mr. Chen Chi-Yuan spoke of his country's developments and said that the People's Republic of China put her first five-year plan into execution in 1953, specifying that within five years the total industrial production value should be doubled. In order to meet the requirements of this plan the power industry had to be vigorously developed through the construction of new power plants and a renovation of the existing installations. By 1957 the plans call for an annual production figure of 15·9 billion kWh, with an increase in generating capacity of 2 million kW.

Some 76 of the 92 power-station projects are thermal stations, the remainder being hydro-electric installations. Within this five-year period, the unified planning for a multi-purpose utilisation of the water-power resources of the Yellow River will be completed, and its first-stage engineering project will com-

mence with the construction of the San-Men Gorge plant, with an ultimate capacity of 1,000 MW.

The largest hydro-electric plant now in commission in China is the Fung-Man plant. As part of the first five-year plan renovation of this plant has been carried out, with assistance from the USSR. Damage to the dam has been rectified, removing the threat of further trouble, and all the machines have been equipped with automatic control. When this renovation operation is completed in 1957, the generating capacity of the plant will be 567 MW.

The proposal to foster multi-purpose utilisation of all available sources has led to the initiation of construction work on seven hydro-electric plants of 10 to 100 MW capacity each, and eight smaller installations. There will, therefore, be a considerable increase within the five-year plan of hydro-electric generating plant, and the total power production from water-power sources will be raised from 9·3% in 1952 to 17·1% in 1957. Preparations are also being made for the utilisation of water-power resources along the main stream and the principal tributaries of the Yangtze river and the rivers in the Lhasa district.

The first five-year plan is principally concerned with the installation of regional power stations, whether thermal or hydro, of comparatively large capacity which will be interconnected throughout the country by means of ten high-voltage transmission networks. The supply of equipment and the technical assistance necessary for the construction of these plans mainly come from the USSR and other People's Democratic Nations. The remainder of the equipment is of Chinese manufacture, or is supplied by Western and Northern European countries. On the manufacturing side, power plants equipped with 10,000 kW hydro-electric generating units and 6,000 kW turbo-generators, all of Chinese manufacture, are now in commission. A Chinese-designed remote-controlled hydro-electric plant of 6,000 kW in the vicinity of Peking will be commissioned this year.

Mr. Chi-Yuan then went on to discuss the future development of power in China. He said that the direction of the future development of the power industry lies in the development of her water-power resources. China is one of the countries abundant in potential water power. The total that could be developed theoretically, according to the average flow rate of the rivers is estimated to be 540 million kW, of which 40% would come from the Yangtze river and its tributaries, 21·3% from the Tibet river systems, 16·7% from international rivers in south western China, 6% from the Yellow river, and 5·2% from the Pearl river in south China.

The conditions for the development of water power in China are stated to be technically and economically favourable. Almost all the large industrial centres are within the supply area of the hydro-electric power plants, an outstanding example being the famous "Three Gorges" site on the Yangtze river, which is located about 250 km. up river from Hankow, and has a capacity of over 10,000 MW. It has been found, also, that where coal resources are scarce water power is plentiful. The topographical and geological conditions of many rivers are especially suitable for the construction of hydro-electric plants, because there are a large number of gorges with steep river slopes from which great flows of water can be obtained at comparatively low construction costs.

According to the preliminary plans now under consideration the total generating capacity of all the hydro-electric plants by 1967 would be about 40% of the total installed capacity. The unified planning of the water-power development has already been completed, and it envisages the construction of 46 hydro-electric stations. During the first period of development the construction of the San-Men Gorge and Liu-Chia Gorge projects will be started. After completion they will generate 10 billion kWh per annum. Extensive investigation and survey work on the Yangtze river has already begun, and the planning of its multi-purpose development is already in progress.

In the planning of the future development of the power industry special emphasis will also be placed on the extension of the existing power-system network and the construction of new transmission lines. Within the next ten years there will be nine 220 kV transmission networks emanating from the large central hydro-electric stations, and these will be interconnected to form a united power system, which will handle about 80% of the total generating capacity of the whole country. Plans for 400 kV transmission lines are under consideration. It is expected that in the second five-year plan China will be able to manufacture turbo-generators of 100,000 kW capacity, and hydro-electric generating units of 100,000 to 150,000 kW. Technical research organisations and laboratories are now being established.

(To be continued)

An Italian Consulting Service

A new consulting service has recently been set up by a consortium of Italian organisations under the name of Electroconsult, 13 Via Felice Cavallotti, Milan, and we have just received the English edition of a handsome brochure setting forth the organisation, personnel and scope of this new concern. Although the organisation itself is new it represents the pooling of extensive experience in the field of power-plant design, for it has been promoted by three Italian concerns of world-wide repute and can draw on the experience of engineers of international reputation. The three organisations involved are Soc. Adriatica di Elettricità, Fiat, and Montecatini. The body operates purely in a consultative capacity, and is not tied to any particular contractors. Such contracting or manufacturing facilities in the power-supply field as the individual firms possess are not allowed to influence the position.

Wire-Belt Slings. The British Wedge Wire Co. Ltd., Warrington, Lancs., have issued a pamphlet describing wire-belt slings for lifting engineering and industrial apparatus. As the sling is fully articulated there is no flexure of the wires used in its construction, so that fatigue is reduced to a minimum. The greater width of the sling as compared with a rope provides better load balance and gripping power, and the danger of damaging the load is correspondingly reduced. Each sling is tested to twice its working load before dispatch by a recognised testing house, and a certificate issued.

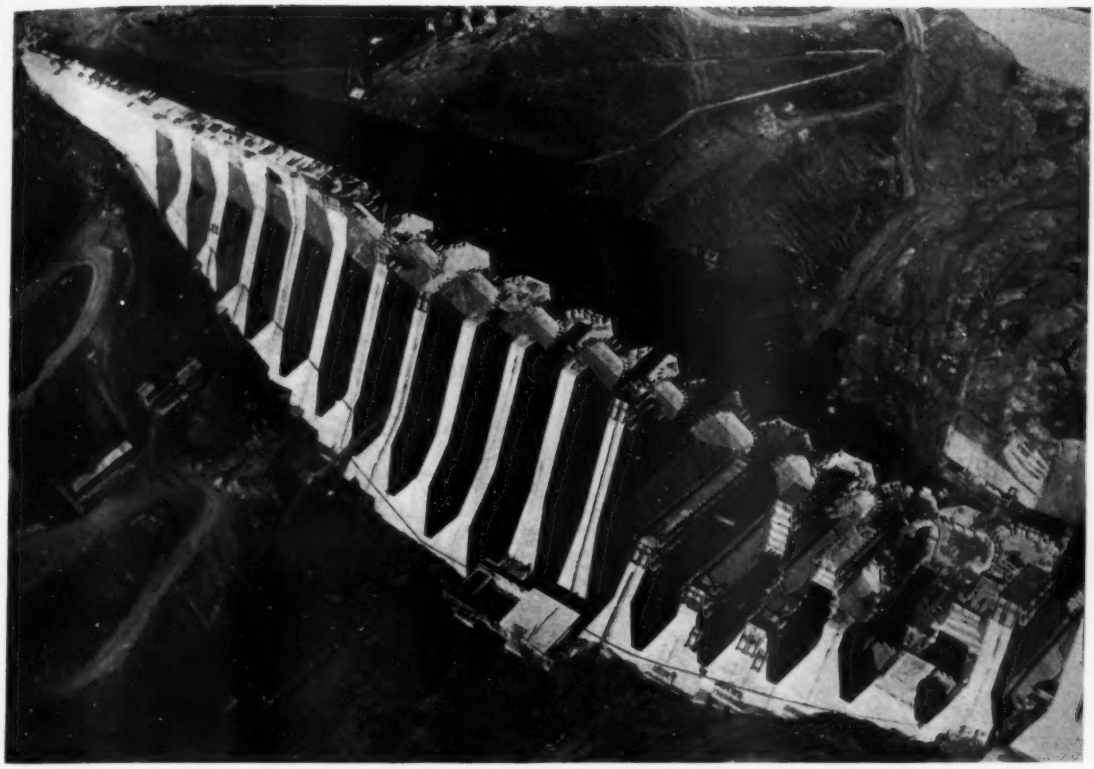


Fig. 1. Ben Métir dam in course of construction

The Ben Métir Dam

Some difficult design problems were posed in this Tunisian development by the unsatisfactory nature of the terrain. These articles explain in detail how these problems were solved.

By A. STUCKY

CONSULTING ENGINEER, PROFESSOR AT
L'ECOLE POLYTECHNIQUE DE LAUSANNE

PART ONE

THE basin of the El Lil river, 150 km. west of Tunis, has an area of 180 sq. km. It is formed by a circle of mountains of moderate elevation and consists of oligocene sedimentary rocks with alternating beds of sandstone and marl. In a recent geological period the centre of area was occupied by a small natural lake, and the deposits accumulated from this lake in the course of the centuries now cover the bottom of the Ben Métir basin. The dam is located immediately downstream of the confluence of the El Lil and the Lebgu, and artificially restores this lake by replacing an ancient barrier destroyed by erosion.

The maximum storage level has been fixed at 440 m.—65 m. above the bed of the river. An area of 350 hectares is inundated, providing a storage of 73 million cu. m. The annual average river discharge of 60 million cu. m. corresponds to a mean flow of about 2 cu. m. per sec.

A tunnel, 3,500 m. long, driven in the right flank of the valley, emerges downstream of the dam about

200 m. above the river bed. This head is utilised in two power stations in sequence which return the water to a compensating reservoir which forms the drinking-water supply for the town of Tunis.

Character of the Foundation

The location of the dam was determined by a narrowing of the valley below a funnel-shaped basin which forms a continuation of the valleys of the El Lil and Lebgu. Although the topography was particularly favourable, as it enabled the desired storage to be obtained with a dam having a crest length of some 480 m., the character of the foundation was quite the reverse.

A second site was considered, 400 m. farther downstream in the El Lil gorge, to the right of a relatively important outcrop of sandstone strata, but an examination of the geological conditions showed that these strata, which had been strongly subjected to uplift, rested on beds of marl. It was the collapse of this marl, which had been partly carried away by erosion, that had caused the dislocation of the sandstone, and it was felt that this process might continue. The upstream site was therefore finally chosen.

The results of the preliminary survey, confirmed by an extensive programme of borings carried out after work had begun, and followed by the foundation work itself, showed that the oligocene clay-sandstone series appears on the right of the dam in the form of relatively flat beds of sandstone and marl, the mean dip of which is 23° to the north-north-west, that is, in the upstream direction and towards the right bank. These relatively thin beds form a complex system which outcrops over about three-quarters of the length of the

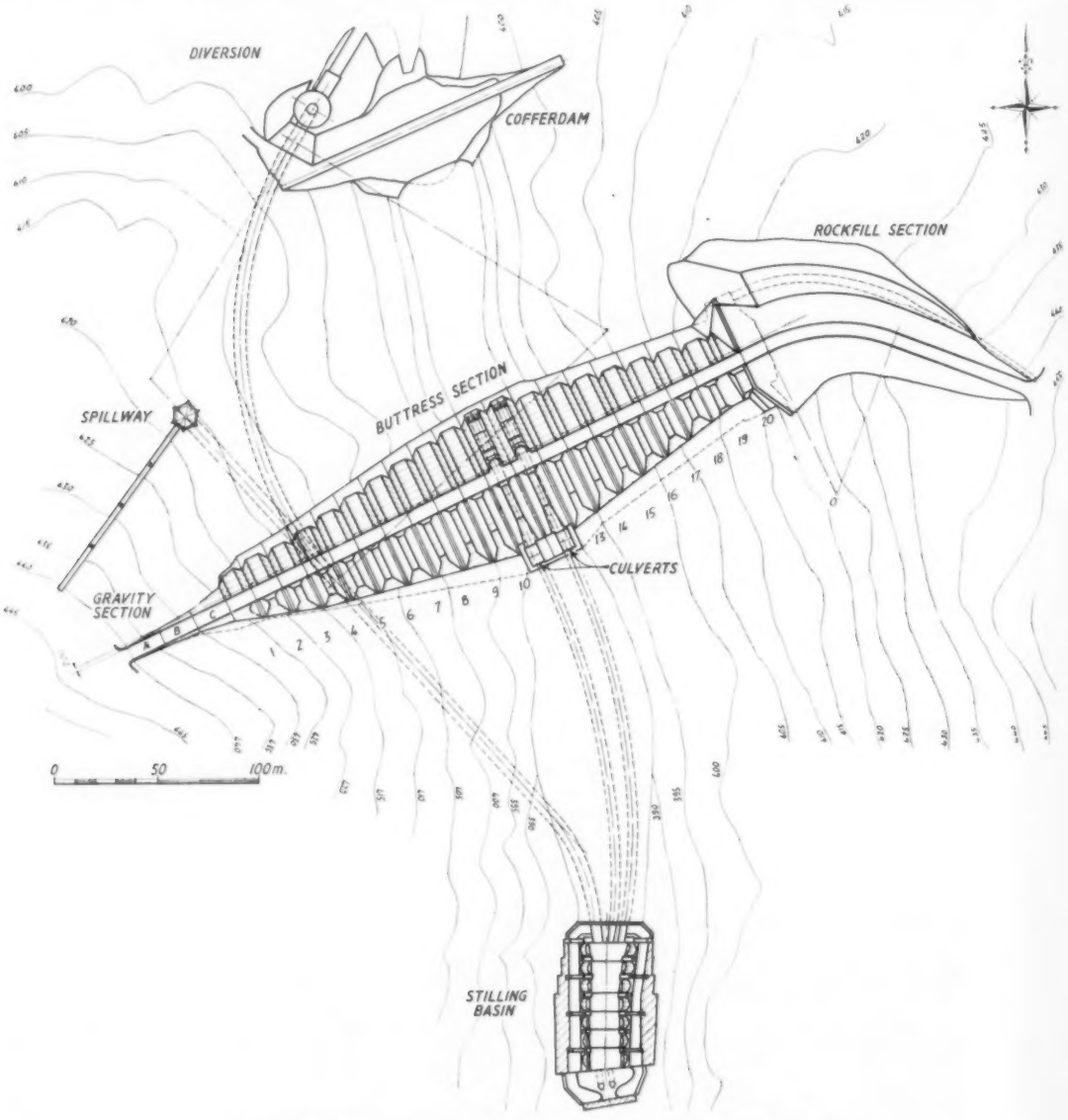


Fig. 2. General plan of Ben Métir dam and associated works

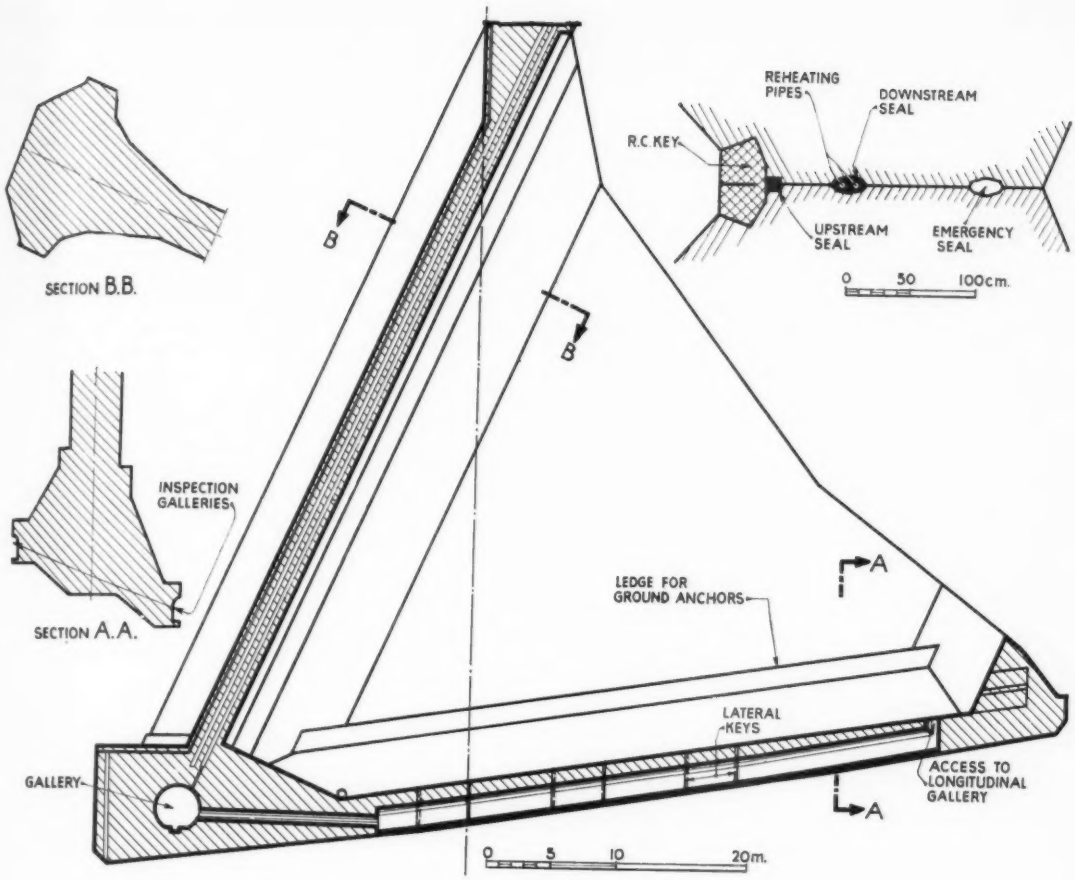


Fig. 3. Longitudinal section through a typical buttress

dam site. To the right of the left abutment it disappears, due to its dip, under a thick covering of unconsolidated lake deposits.

In these conditions it was not possible to find a continuous and resistant bed on which to build the dam.

The sandstone beds, of quartz formation, are soft and fractured. None of the beds is more than 4 m. thick, and furthermore, this thickness varies from one zone to another to such an extent that in places the beds disappear and become no more than a succession of lenticles of more or less weathered sandstone submerged in argillaceous beds. In contrast to the beds of marl, which are compact at depth and more and more weathered as the surface is approached, the deeper sandstone beds are very dislocated, whereas those nearer the surface are less so. The sandstone beds are very permeable and form a region of water percolation. None of them could form the foundation for the buttresses, except that supporting buttress No. 20.

The beds of marl are firmly consolidated at depth —a fact that was disclosed by preliminary borings and was confirmed when the diversion tunnel was driven. This marl is a soft rock, dark grey in colour, possessing good mechanical properties. The strata, which outcrop below the dam, are usually very thick, ranging from 8 m. to many tens of metres. In general they are impermeable, but are very sensitive to any change in constraint or in physico-chemical state, which is accompanied by the appearance of numerous diabases. At the surface they are subjected to a release of compression which has caused them to swell, and this necessitates cleaning-off to some depth to reach sound rock.

The softer and less homogeneous argillaceous beds are interspersed with beds of sandstone. They contain numerous sandstone lenticles, and outcrop on the left bank of the valley.

The lacustrine deposits, which rest on the other formations, are not consolidated by anything beyond their own weight, and have not been subjected to tectonic forces. They are weak in comparison to the oligocene formations, and appear as more or less sandy clays, reddish in colour.

Choice of Type of Dam

In the soundest portion of the site chosen for the dam the marls and sandstones outcrop over a large part of the profile, but upstream, on account of the 23° dip, the strata descend deeply under a thick deposit of unconsolidated detritus which is liable to slide. Downstream of the site, the bed and the two sides of the valley are covered with unstable material in con-

stant movement from landslides, to such an extent that during the construction period it was necessary constantly to dry out and consolidate the terrain to prevent interference with the workings.

Under these conditions an earth dam could not be contemplated, especially as satisfactory material could not be found within a reasonable distance. A gravity dam, also, could not be entertained because of its over-rigidity and particularly because the stresses at the downstream toe would have been too high.

The only feasible type was a dam with buttresses long enough to enable the pressures on the soil to be kept within moderate limits. Calculations, however, indicated that the arches of an arch-headed buttress dam, although very thin and strongly reinforced, could not withstand the probable settlements of the buttresses without grave risk of disaster.

The character of the marl-sandstone complex demanded a relatively flexible structure capable of withstanding without damage irregular and major settlements reaching values up to 10 cm. To limit these settlements and avoid dislocation of the upper strata it was desirable to keep the maximum pressures exerted by the structure on the terrain to the lowest possible value, and to load the ground as evenly as possible. Finally, as the internal friction of the argillaceous beds and the friction of concrete on clay was low, it was desirable to take precautions against the danger of the buttresses sliding downstream under the water pressure.

These conditions led to a design consisting of buttresses with jointed polygonal heads, and in such a design the upstream dip was very favourable from the standpoint of preventing sliding. In the region of the left wing the lacustrine overburden has such a high degree of compressibility that the erection of a concrete structure was precluded, and it was necessary to construct this part of the dam in rockfill.

Description of the Dam

The Ben Métir dam (Figs. 1 and 2) consists of three sections, each different in design to suit the ground beneath it. The main body, which is founded on heterogeneous beds of the argilo-sandstone complex, is a plain concrete structure divided by vertical joints into 20 independent buttresses. The right wing, which

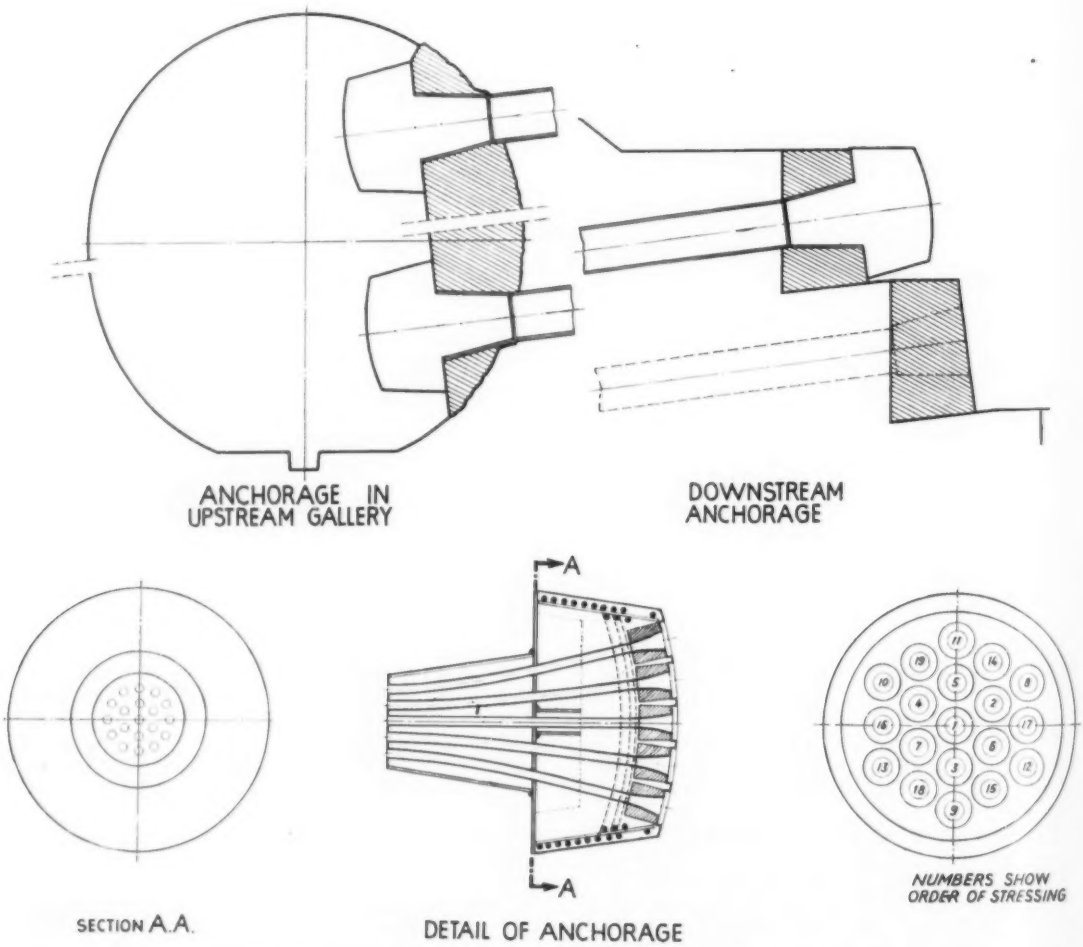


Fig. 4. Details of arrangement for longitudinally prestressing the foundation plinth of a buttress if this is found to be necessary

it was possible to site entirely on a continuous bed of sandstone, is a simple solid gravity dam in plain concrete but divided into three independent blocks *A*, *B* and *C* by joints which enable the blocks to adjust themselves to any probable settlement. The left wing, as already stated, is a rockfill embankment with a reinforced-concrete impervious membrane on the upstream face.

The Buttress Section

The buttresses are separated by vertical joints at 14 m. intervals which render them completely independent; they can therefore accept unequal and relatively large settlements. A buttress dam with a large base area also offers the following advantages over a gravity dam:—

(a) The stresses normal to the foundation are distributed practically uniformly, as against the triangular distribution characteristic of a gravity dam.

(b) The variations in stress due to extreme changes in water level are very moderate.

(c) Heat dissipation from recently placed concrete is effected naturally without the need for special measures.

(d) It is easy to provide for strengthening works in the region of the foundations, which remain accessible.

With the exception of the central buttresses which carry the emptying culverts, and buttress No. 20 which forms the transition to the left-hand rockfill section, all the buttresses are of the same type (Fig. 3). Their profile is substantially triangular, the slopes of the upstream and downstream faces and the gradient of the base having been determined so as to afford adequate resistance to sliding and to distribute the load on the ground as evenly as possible, while keeping the total volume of concrete to the minimum.

Each buttress is in unreinforced concrete and has an upstream head 14 m. wide set at an inclination of 1:0·45, the heads of the buttresses forming a continuous face. Each head is supported by a web, 4 m. thick, which transmits the load to the foundation plinth.

The profile of the head has been chosen to avoid tension stresses due to the water pressure, and has been made polygonal so that the water pressures on the various faces converge towards the axis of the buttress. On the downstream side of the head a large gusset transfers the load evenly to the web.

The foundation plinth is also mated to the web by a heavy gusset, and the various plinths are jointed in such a manner as to limit the load on the foundation rock as far as possible. This load does not exceed 9 kg. per sq. cm. under the highest buttress. The marls are also protected from the desiccation and disintegration to which they would be subject if they were exposed to the air. Finally, the foundation plinths are sloped upwards towards the downstream toe to increase stability against sliding, the average slope being 15° except for the heavier central buttresses, where it is reduced to 10°. To avoid a heavy stress concentration at the upstream and downstream extremities, the foundation has been made polygonal in plan and has a slightly smaller slope at the upstream end. The ends of the plinth terminate in a 1 × 1 m. chamfer.

The dimensions and shape of the buttresses have been chosen not only to limit the ground pressure to 9 kg. per sq. cm. but also to limit the variation of pressure between the empty and full conditions. Thus for the highest buttresses the foundation pressure ranges from 8·3 to 8·5 kg. per sq. cm. upstream and from 4·7 to 7·6 kg. per sq. cm. downstream as the reservoir level changes from low to high water.

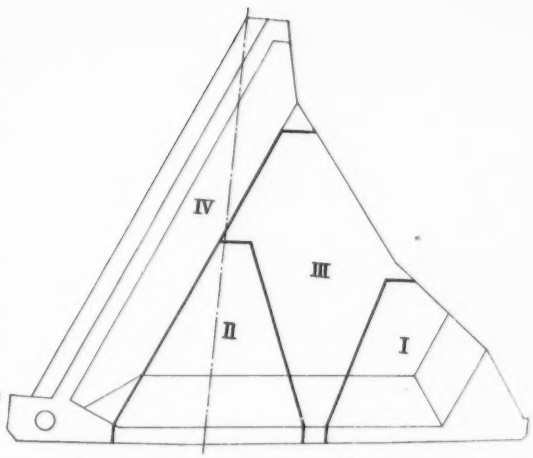


Fig. 5. Concreting sequence for a buttress

A gallery of minimum cross-section has been arranged along the length of each foundation joint to allow for inspection and to minimise and control uplift pressure. This uplift pressure is further reduced by the drainage system described later.

The downstream end of the plinth is reinforced to form a heel which keys into the ground. The upstream, toe, also reinforced, contains a gallery 3 m. in diameter from which the grout curtain and general foundation grouting were executed. This toe projects a few metres upstream in order to augment the weight of water holding the buttress, and is a heavy block of concrete designed to withstand relatively large shearing stresses and bending moments.

The resistance of a buttress is normally adequate without this heavy toe and without prestressing, but to allow for a possible concentration of stress due to foundation movement, provision has been made for prestressing any foundation plinth to eliminate tensile stresses. Longitudinal channels (see Fig. 4), 40 cm. in diameter, have been formed in each foundation plinth, extending from the gallery in the toe to the heel of the buttress, by means of cement pipes buried in the concrete. These channels vary in number according to the height of the buttress, the largest number being 11 in buttress No. 10, and each channel can accommodate a steel cable capable of exerting a pull of 600 tons.

The seals in the joints between the buttress heads should remain watertight in spite of a relative movement of several centimetres. The normal copper strip would not meet the requirements, and has been replaced by the following arrangement: The seal proper is made by a black-mastic Igas key, 10 cm. x 12 cm., which is poured hot and tamped. This key follows the upstream edge of the joint and continues over the toe. It is protected on the upstream side by a lightly reinforced cement key. Tests have shown that such a key remained watertight even after a tangential displacement of 8 cm., but as a precaution a

second key, 25 cm. by 15 cm., has been introduced downstream of the first key, filled with fusible Igas melted and poured at 60°C. This key is surrounded by two metal pipes in which steam can be circulated to remelt the compound and fill any voids caused by excessive movements. Finally, a third channel has been formed outside the joint downstream of this second key and communicating with the gallery in the toe. Normally this serves to drain any leakage through the seals, but can be filled with an emergency seal if necessary.

To ensure that each buttress was structurally independent, the joint surfaces of a buttress were washed with Flintkote before the next lift of the adjacent buttress was placed. In case it should be desirable to limit the excessive yielding of any buttress relative to its neighbours, channels have been left in the foundation plinths astride the joints. If necessary, any of these channels could be filled with reinforced concrete by means of the longitudinal inspection galleries, thus locking the two buttresses together. Similar channels have been left in the heels so that concrete keys can be inserted to prevent too great a difference in vertical settlement.

Finally, provision has been made to anchor the buttresses to the ground, if need be, by means of cables extending through sloping boreholes from ledges, 1 m. wide, formed for this purpose at the junctions between the web gussets and the foundation plinths.

For construction purposes each buttress was broken down into independent blocks and daily lifts. In the region of the web the daily lifts were placed to dip 10° upstream, whereas in the vicinity of the upstream head they were horizontal.

To minimise cracking due to concrete shrinkage and to foundation settlement, each buttress was divided into a number of independent blocks, as shown in Fig. 5. Each block was substantially triangular, the surfaces being located to follow as far as possible the lines of minimum shear. Vertical joints in a buttress had to be avoided as they would have corresponded to lines of maximum shear. Each foundation block (I and II) was able to effect part of its settlement independently before the uniting block III was placed, which was done as late as possible.

Central Buttresses, Nos. 11 and 12

Each of these two buttresses, the height of which reaches 71 m. with a length at the foundation of 86 m., carries one of the emptying culverts. These culverts are 3 m. in diameter, and to house them the buttresses had to be made much thicker towards the base. A layer of felt held between several layers of corrugated board is interposed between the steel culverts and the surrounding concrete so that the culverts can expand freely under the water pressure.

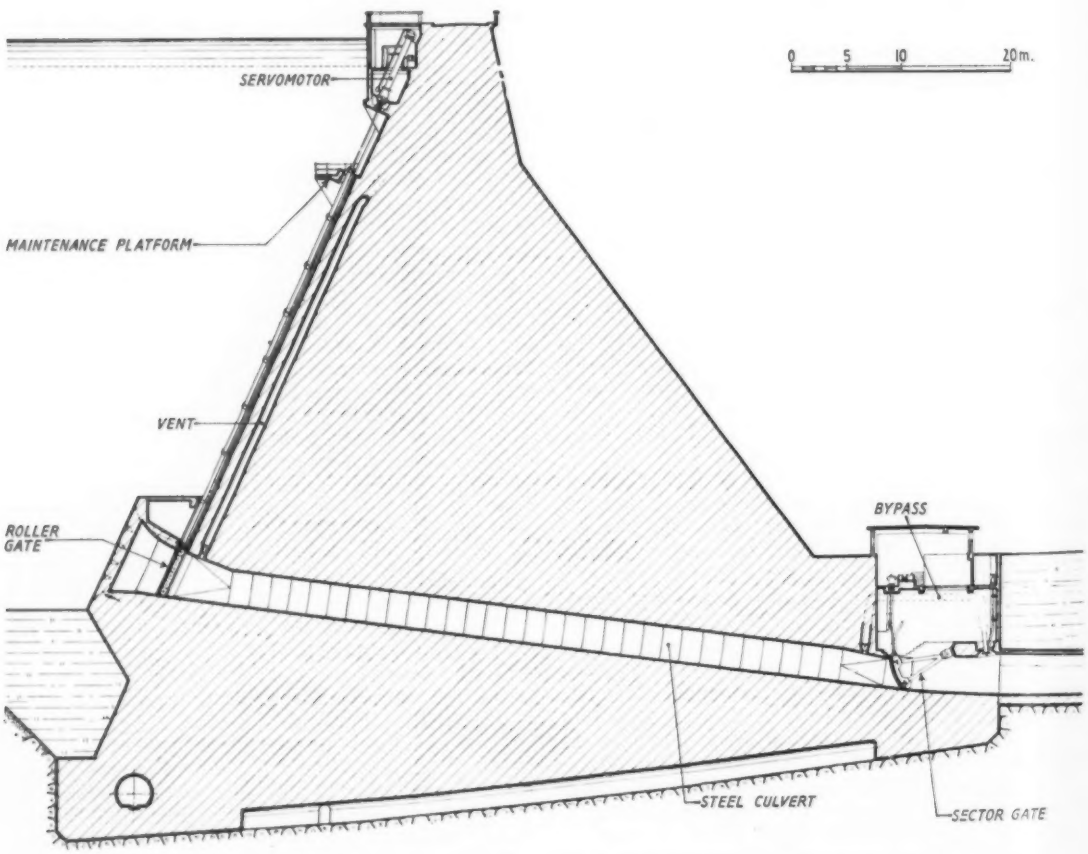


Fig. 6. Section through buttress No. 11 (No. 12 is similar) showing arrangement of emptying culvert

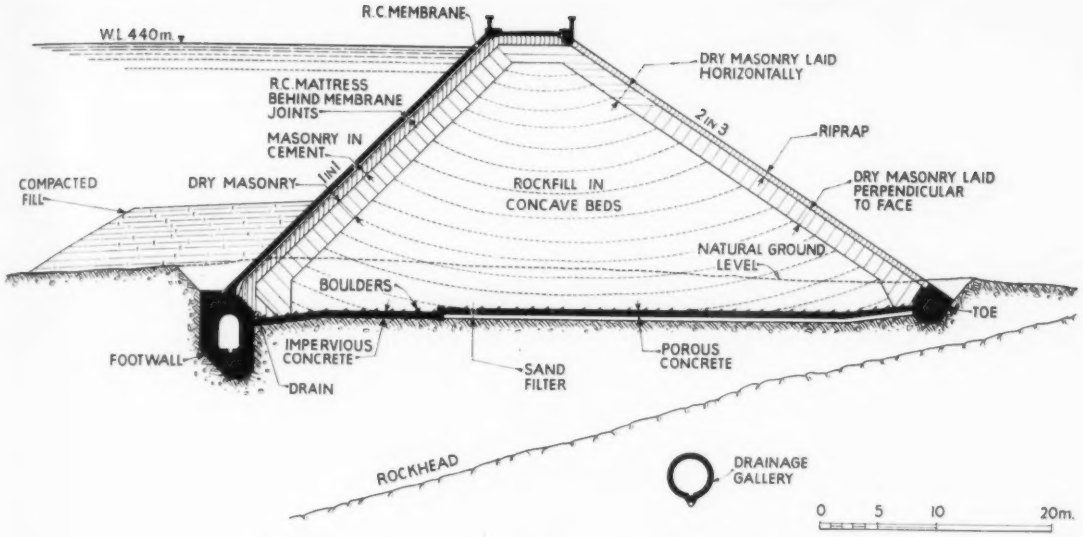


Fig. 7. Section through rockfill section of left wing of dam

Buttress No. 20

This buttress (see Fig. 2) forms the transition between the buttress section and the rockfill section forming the left wing of the dam, and must therefore register on the one side with the adjacent buttress, which has a face slope of 1:0·45, and on the other side with a rockfill section having a face slope of 1:1 and a downstream slope of 2:3. In consequence it has to withstand an oblique water thrust. It has been constructed as an unreinforced concrete monolith standing on a bed of sandstone, and is designed to be stable even without the support of the rockfill, which partly counteracts the component of the water thrust in the direction of the bank. On the rockfill side the buttress has a series of steps, with horizontal and vertical faces, on which the rockfill rests. Thus there is a smooth transition between the concrete buttress, which is subject to very little settlement, and the rockfill, the settlement of which will be more pronounced, so that the watertightness of this zone tends to be assured. The buttress is extended downstream to form a wing wall to retain the rockfill. This wall is rendered independent by means of a vertical joint.

Right Wing

The right wing rests on a continuous bed of sandstone and is a mass concrete structure with a maximum height of 25 m. and with a face slope of 1:0·45 registering with that of the first buttress. To allow for possible inequalities in settlement it is divided into three independent blocks (see Fig. 2), each 18 m. wide, by vertical joints washed with Flintkote and sealed in a similar manner to the joints on the normal buttresses.

Rockfill Section

The rockfill section (Fig. 7) is curved in plan to meet the 441 m. contour level in as short a distance as possible (see Fig. 2). The core consists of slightly concave beds of rockfill built up on a concrete foundation slab in which boulders were set in tooth formation to obtain a rough surface. This slab was poured on ground previously cleaned down to a depth of 3-6 m. The upstream portion has been made in impervious concrete to prevent water infiltration, but the downstream portion is in porous concrete laid on a sand filter to prevent the development of uplift pressure, which is also guarded against by the drainage system described later.

The impervious membrane on the water face is a thin sheet of reinforced concrete which, at the bottom, enters a heavy concrete footwall, below which is a grout curtain. This membrane has no horizontal joints but has a series of transverse joints following the lines of greatest slope and spaced 5 m. apart at their intersection with the footwall. The footwall is articulated every 20 m. Behind the membrane joints are reinforced-concrete mattresses carried in a 1 m. thick bed of masonry set in cement mortar. This masonry layer in turn rests on a 2 m. bed of dry hand-placed masonry. Between the impervious membrane and the mortar-set masonry layer is a layer of porous concrete, 20 cm. thick, to receive any leakage. Drains, 6 cm. in diameter, lead from this layer to a drainage gallery in the footwall. The joints in the impervious membrane are sealed by an Igas mastic key protected by a reinforced-cement key, similarly to the joints between the buttresses.

The downstream face consists of a 50 cm. layer of riprap resting on a 1·60 m. layer of dry masonry. It is supported by a small concrete footwall.

NOTE. The substance of this article originally appeared in French in *Bulletin Technique de la Suisse Romande*, and the English article has been prepared in collaboration with the author.

(To be continued)

Waterstops. Expandite Limited, Chase Road, London, N.W.10, have issued leaflets relating to PVC and rubber waterstops for use in concrete structures, and to guns for the rapid application of Seelastik and Asbestumin sealing compounds.

Fig. 1. Left bank of Castlereagh dam site, May 25, 1956

The Ceylon Hydro-Electric Scheme

The first stage of Ceylon's hydro-electric system was commissioned in 1950 and has a capacity of 25MW. The second stage, now under construction, will provide sufficient storage to double this capacity

THE Ceylon hydro-electric scheme, often referred to as the Aberdeen-Laksapana scheme, is located in high country situated in the central part of the Island as indicated in Fig. 4. This is the area of the highest rainfall in Ceylon. The second stage of development, as an extension to the first stage, is now under construction.

Since the commissioning of the 25,000 kW of hydro-electric plant of Stage I of the scheme in October, 1950, some 95 per cent. of the electrical energy generated in the system has come from this source. The existing thermal plant acts as standby to supplement the load as occasion demands. In general, the steady price of power in a world of rising costs is shown in Fig. 3. The figures have been taken from the latest report by the Chief Engineer and Manager of the Department of Government Electrical Undertakings.

Between 1950 and 1954, the system peak rose from 14,000 kW to 30,000 kW making urgent the installation of further generating plant. The second stage of the scheme was, therefore, put in hand and contracts were let in the latter half of 1954.

Stage I of the scheme employs the waters of the Kehelgamu Oya between Norton reservoir, situated upstream of the Aberdeen Falls, and at an elevation of 2,844 ft., and the Laksapana power house, with machine floor at an elevation of 1,275 ft., by diverting them through a tunnel into the neighbouring valley of the Maskeliya Oya alongside which the Laksapana power house was built a short distance downstream of the Laksapana Falls. The catchment of the Kehelgamu Oya above Norton dam is about 65 sq. miles. It is steep and rocky and subject to intense rainfall during the five or six months when the south-west monsoon prevails, with much more moderate falls during the rest of the year. The average annual rainfall as measured at Norton dam is about 220 in. The Kehelgamu Oya is, therefore, a very temperamental

Fig. 2. Right bank of Castlereagh dam site, May 25, 1956

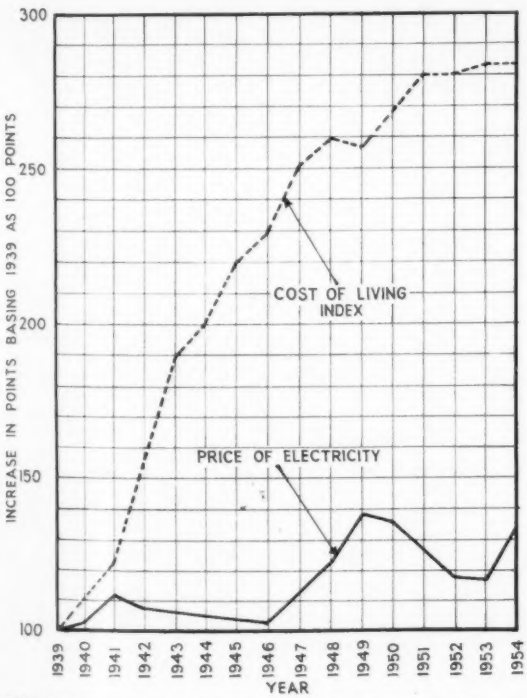


Fig. 3. Price of electricity compared with cost of living

river, variations of flow from 30,000 cusecs to 44 cusecs having being recorded. The intake for the 8,400 ft. long tunnel constructed under Stage I is at the Norton reservoir, which has limited storage capacity, little more than sufficient to take up the diurnal and weekly load variations.

The installation of plant under Stage I was, therefore, limited to that justified by the dry-season flow together with a limited amount of thermal backing, and during the wet season large quantities of flood water continue to run to waste.

Fortunately, some five miles upstream from Norton dam at Castlereagh, there is a suitable site for seasonal storage and the development of this storage is now under construction and is part of the second stage of the scheme, known as Stage IA. This will allow a further 25,000 kW to be generated. This development had been foreseen so that the intake structure, tunnel and surge chamber in Stage I had been designed with Stage IIA in view. The plan of development is shown in Fig. 5 which is a scaled map of the locality. Fig. 6 shows the two stages of development in diagrammatic form.

The Castlereagh Dam

Some five miles upstream from the Norton dam, the valley widens into a large flat area of several hundred acres. The outlet from the flat, which appeared to offer an ideal dam site, proved when bored to be unsuitable due to excessive overburden on the left bank. Some 3,000 ft. downstream a more suitable site was found

but where a higher dam is necessary to produce the required storage. The dam, as designed, will be a mass concrete gravity structure some 711 ft. long with a height at maximum section of 142 ft. from foundation to the spillway crest at an elevation of 3,590 ft. It will carry a reinforced-concrete bridge above the spillway supported on piers providing 14 openings, each 30 ft. wide, for flood discharge. The bridge will form part of the main highway between Hatton and Norton Bridge.

The gross volume impounded up to spillway crest level will be some 49,000 acre ft.

At some later date it is planned to develop the fall of approximately 750 ft. between the Castlereagh and Norton dams (known as Stage IIB) but in the interim the water stored in Castlereagh reservoir will be released and will be fed down the river bed to the Norton reservoir as required. To this end there is embodied in the design a pipe culvert 6 ft. in diameter protected at the upstream end by a coarse screen and a roller emergency gate. At the downstream end a remote-controlled needle valve and jet disperser will be fitted. In this manner draw off from the Castlereagh storage can be controlled to the requirements at Norton reservoir which supplies the varying demands of the water turbines.

Borings show that the dam can be founded on hard gneiss (Charnockite) with a dip of about 45° towards the left bank and a strike that is roughly parallel to the run of the river.

The gneiss is garnet bearing in places and elsewhere shows narrow veins of crystalline limestone and mica. In view of limited intrusions of weathering, provision has been made at the heel of the dam for a cut-off trench and for deep grouting. Behind this grout curtain, drainage holes and a drainage system will relieve uplift.

Downstream of the dam five vents at either end of the spillway will spill into steep sloping channels which will form part of the dam itself. These side-slope channels and the main centre spillways will discharge on to an apron, at the downstream end of which a weir, 9 ft. high, will create a stilling pool 100 ft. long by 100 ft. wide.

Essential concrete work for the intake of the future Stage IIB tunnel is provided for under the present contract. It will lie within the impounded area of Castlereagh reservoir and it has been designed to accommodate future gates and screens suitable for 1,000 cusecs.

Station Supply Conduit System

As the intake, tunnel and surge chamber of Stage I were constructed with the present extension in view, the intake structure was built with four gates and screen bays, only two of which were then equipped with screening plant. The present works include the supply and installation of two further screens. The tunnel was designed for a flow of about 550 cusecs.

Similarly, at the surge chamber, the structure provides for the accommodation of two bar screens, only one of which was installed. The second screen is now to be supplied and erected.

At the outlet from the surge chamber, two 68 in. diameter pipes were embedded in a concrete plug. One of the pipes was temporarily blanked off and it will serve the pipeline now under construction. This pipeline will consist of a single 68 in. pipe as far as the first anchor where it will bifurcate and continue as twin pipes of 48, 44, 40, 36 and 33 in. diameter, similar to the two existing pipelines. The 33 in. pipes at the foot were designed to withstand a head of 1,820 ft., including water hammer.

In the present case, the pipes are wholly of electrically welded construction. As previously, each will be equipped with a 48 in. diameter butterfly self-closing valve, with over-velocity trip paddle, housed with air valves and drains in an existing valve house at the head of the pipeline. Isolating valves and turbine-inlet valves will be located at the foot of the pipelines. The two new pipelines will be interconnected with each other and with the existing pipelines through isolating valves as shown in Fig. 6.

As for Stage I, the pipes will be supported by about 50 ft. intervals on roller saddles and anchored at 12 anchor blocks, an expansion joint and manhole being provided in each leg between anchors. The low friction coefficient of the rollers allows considerable reductions in the amount of concrete of saddle supports and anchors to be effected.

The Laksapana Power House

The existing power house building is 144 ft. long, 84 ft. wide and 70 ft. high. The machine room is 42 ft. wide and the floor is at an elevation of 1,275 ft. The structure is steel framed with reinforced-concrete floor slabs and walls. An outside gantry allows the transfer of transformer units from their stalls to the workshop, where they can be handled by the 50 ton crane. The

Fig. 4. Map of Ceylon showing the location of the power house

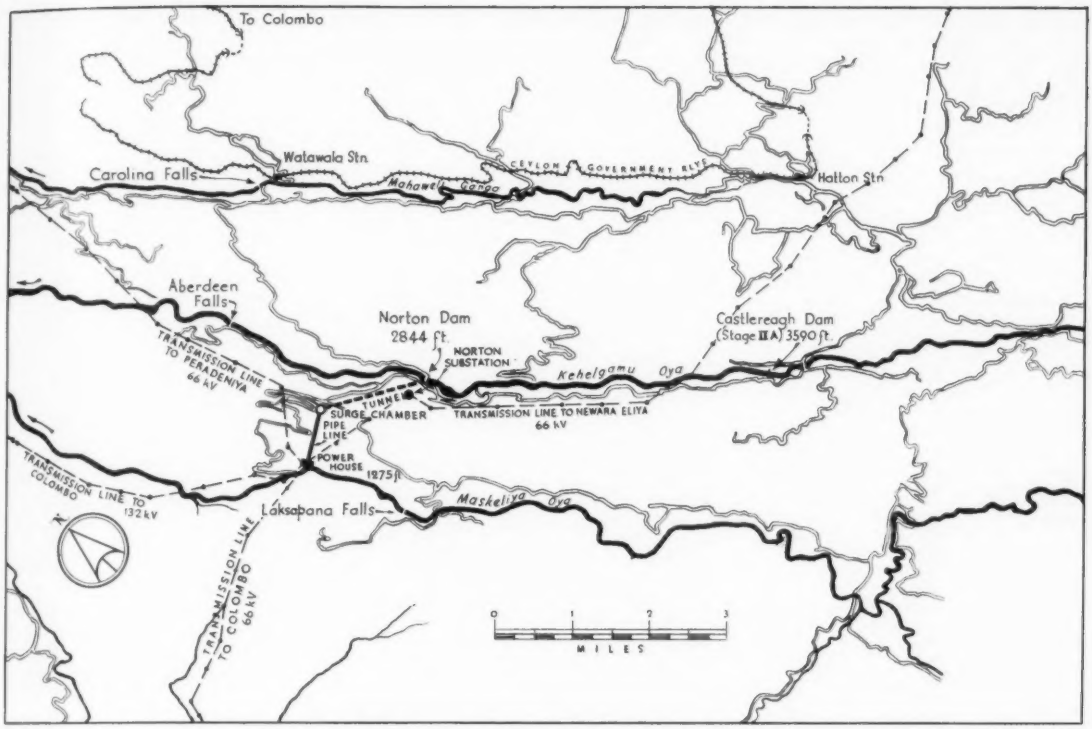


Fig. 5. Locality map showing the plan of development

present extensions will increase the length to 256 ft. Whereas the existing crane stanchions and machine blocks are founded on rock, the extension will be largely founded on a concrete raft.

The existing generating plant consists of three 8,333 kW alternators each driven by a double-jet Pelton turbine operating under a nominal head of 1,500 ft. and running at a speed of 600 r.p.m. Each alternator is designed for generation at 11 kV, 0·85 power factor and for an overload of 25 per cent. for two hours. The Pelton is governed by spears equipped with special diffuser blades. Both the pendulum and pump of the governor are belt driven, and a special hand pump has been provided for opening the spears when no pressure is available in the pressure vessel for starting. The main turbine-inlet valves are of the cylindrical balanced type hydraulically operated.

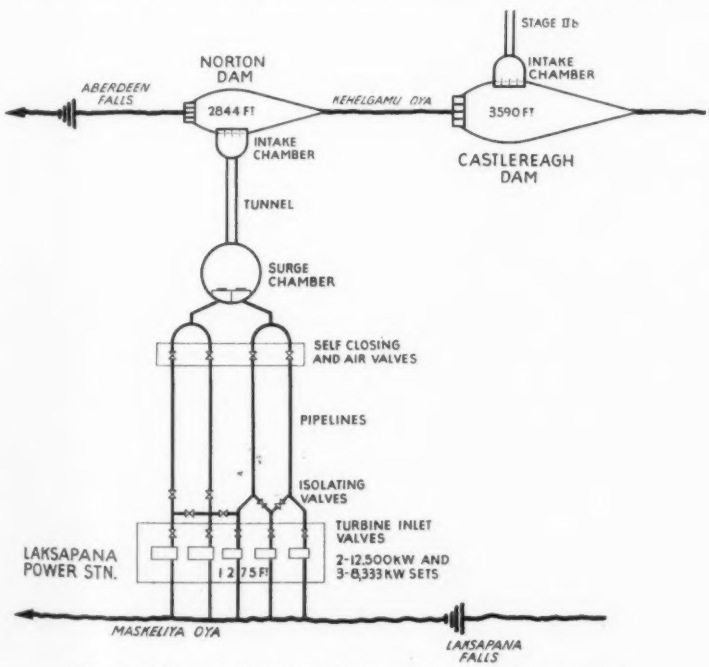


Fig. 6. Diagram showing the two stages of development

The power-house extension under Stage IIA will house two double-jet Pelton turbines driving 12,500 kW alternators running at 500 r.p.m. As previously, the alternators are being designed for generation at 11 kV at 0·85 power factor and for an overload of 25 per cent. for two hours. The Pelton turbines will be governed by deflectors and spears, and the governor pendulum in each case will be driven by a synchronous motor supplied from a generator mounted on the alternator shaft. The governor oil pump will be driven by an electric motor, but a pump driven by a small Pelton set is being provided for emergency

starting. The main turbine-inlet valve will be of the spherical type hydraulically operated and capable of being closed against full head. These valves, like the existing turbine valves, will be actuated by pipeline water pressure and can be operated by pushbutton either locally or from the control room, or automatically on overspeed, pendulum-motor failure, low oil pressure in the receiver, and overheating of bearings.

The main exciter will be located between the rotor spider and the main bearing, thereby reducing the overall length of the set. The pilot exciter will be overhung.

The alternators will be cooled normally by a closed ventilation circuit, the air being passed through tubular water coolers situated in the pit below the machine and each having its own cooling-water pump with suction in the tailrace, but a system of louvres will be provided in the machine and in the pit wall to allow of direct ventilation in the event of the cooler being withdrawn. This will be effective up to 80 per cent. full load.

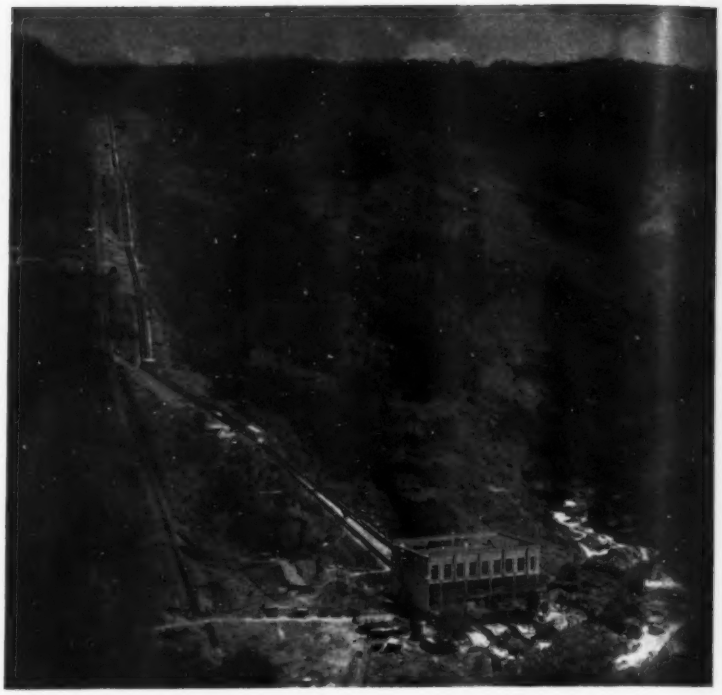


Fig. 7. Laksapana power station at Stage I

An alarm system and signal lamps will give warning of high outlet-air temperature, cooling-water failure, high bearing-oil temperature and low governor-oil pressure.

Each alternator, as in the case of the existing alternators, will be provided with an automatic voltage regulator and normal field protection, and the neutral will be earthed to the station earth system through the primary of a special transformer, the secondary of which will be connected to a resistor.

Each alternator will be direct connected to its 15,000 kVA 11/132 kV bank of single-phase transformers through an isolator cubicle which will enable either alternator to be connected through a circuit breaker to the test tank. Circulating-current type of protection will be provided across the alternator and transformer bank. The high-voltage side of the transformer banks will be earthed through arc-suppression coils to reduce outages from lightning and other transients.

Switchyard

The high-voltage busbars of Stage I are at 66 kV as opposed to the new high-voltage busbars which will be at 132 kV. Inter-connection between the two sets of bars will be arranged through a 15,000 kVA 66/132 kV transformer bank with remote-operated on-load tap-changing gear.

Switching takes place in a yard immediately behind the power house. The existing 66 kV switchgear provides for four outgoing circuits, two forming the present line to Colombo. The circuit breakers are of the bulk-oil type. Double 132 kV busbars arranged vertically will be provided under the present contract. The 132 kV layout provides for the two alternator-transformer incomers, the interconnector, a bus coupler, two outgoing circuits for a transmission line to Colombo now under construction and four future outgoing circuits. The present contract also includes two 66 kV outgoing circuits from an extension of the existing busbars. All switchgear in the present contract will be of the small-oil-volume type. Fig. 11 is a single-line diagram of the system.

Transmission

Although in the foreseeable future Colombo and district must continue to be the principal centre of power consumption, the high-tension transmission system has been extended to cover other areas, such as the tea estate and the coconut estate areas, where load growth has been fostered either by a 33 kV distribution system or by independent small stations. The existing transmission lines consist of a 66 kV double-circuit transmission line to Colombo and a double-circuit line to Peradeniya, both lines using copper conductors in the level country and cadmium-copper conductors in the hilly country.

Transmission lines under the present contract include some 52 miles of 132 kV double-circuit line from Laksapana to Colombo; some 48 miles of 132 kV double-circuit line part northwards along the coast from Colombo to Bolawatta and part north-westwards from Peradeniya to Kurunegala, both of which will be operated for some years at 66 kV pending foreseen load growth in the areas served. In addition they also include some 44 miles of 66 kV double-circuit line running westwards from the Lakspana power station through the tea districts to Nuwara Eliya and Badulla. All the transmission lines will have lattice steel towers carrying steel-cored aluminium conductors. In the case of the transmission line northwards from Colombo which parallels the coast, conductors with greased core

Fig. 8. Outdoor switchgear area and power-house columns, May 24, 1956

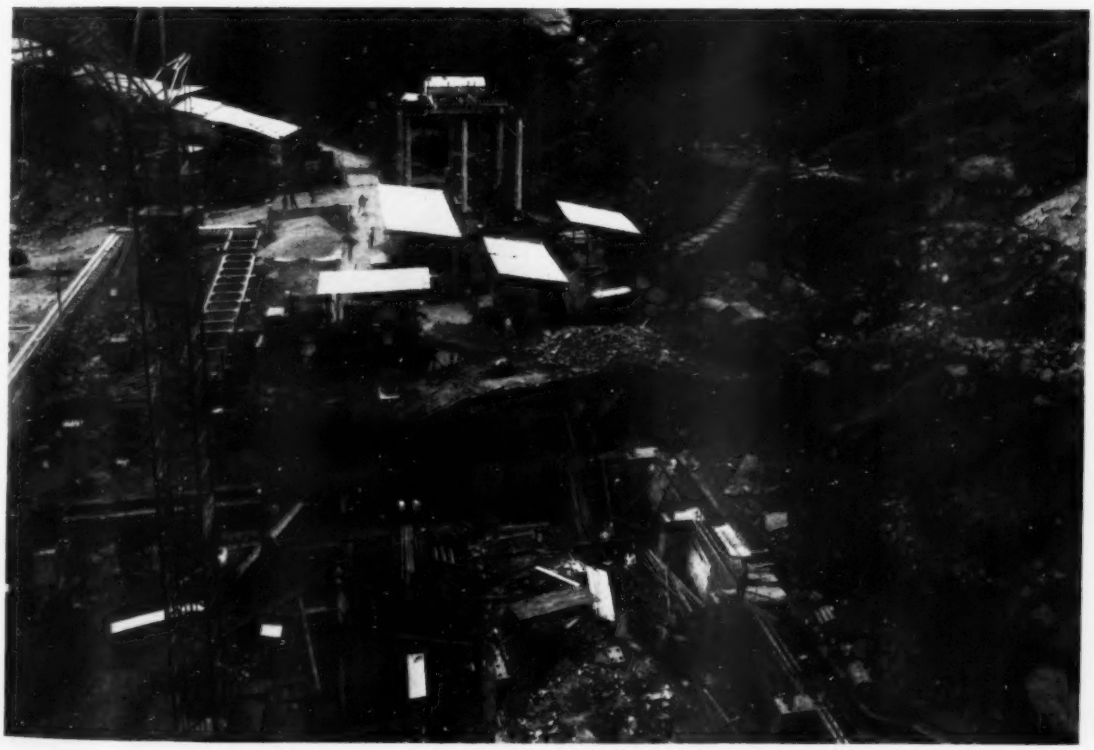


Fig. 9. Transformer bays, concrete-mixing plant and stanchion bases, May 24, 1956

will be employed to resist the salt-laden air which sweeps inland during the S.W. monsoon.

The 132 kV transmission line from the power house to Colombo will be sufficient to provide for the additional power to be transmitted after completion of the next stage of hydro-electric development which is foreseen at an early date. A second 132 kV duplicate-circuit transmission line is contemplated in the future when the increase of load in Colombo and district warrants it. Further transmission lines, to widen the areas served, are contemplated.

Special attention has been given on all lines to protection from lightning, which is both severe and frequent in Ceylon. The 132 kV line to Colombo will be protected by two earth wires, the other lines by a single earth wire except within one mile of terminal points and substations, where two earth wires will be employed. The earth wire or wires at every tower will be earthed by means of copper strip forming a counterpoise system. All 132, 66 and 33 kV lines are earthed through arc-suppression coils.

Receiving Station at Colombo

The existing outdoor substation at Kolonawa, Colombo, is at 66 kV and consists of two incoming 66 kV circuits from Laksapana, a busbar section switch and two outgoings to two 15,000 kVA 66/11 kV step-down transformers, one on either side of the section switch. The 66 kV circuit breakers are of the bulk-oil type. Each bank is connected to its 11 kV remote-operated on-load tap-changing voltage booster, which is connected by cable to a metalclad 350 MVA 11 kV double-busbar switchboard located in the receiving-station building, which also houses an 11 kV 8,000 kVAr synchronous condenser.

The outgoing circuits from the 11 kV switchboard include connections to the Colombo 11 kV distribution board through reactors, to three 3,000 kVA steam sets in the Stanley steam station, of which the receiving station building is an extension, to the transformers serving the 33 kV north and south transmission lines and to local feeders.

The present contract provides for the supply of a 132 kV substation having duplicate busbars with two connections to the incoming double-circuit transmission line from Laksapana, one connection to a 30,000 kVA, 132/66 kV three-phase interconnector transformer to the existing busbars, two connections to two 30,000 kVA, 132/33 kV three-phase transformers and one busbar coupler. The interconnecting transformer will have a 33 kV tertiary winding to serve as a partial spare in the event of a breakdown in one of the main transformers. It has, as well as the 66 kV winding, remote on-load tap-change gear. From an extension to the existing 66 kV busbar, two outgoings will serve the double-circuit 132 kV north line along the coast to Bolawatta, which, as stated earlier, will operate for some years at 66 kV. The main transformers will be connected to an adjacent 33 kV double-busbar substation, the outgoing cable feeders from which will serve the proposed Colombo 33/11 kV substations.

The two 30,000 kVA three-phase 132/33 kV transformers will be equipped with automatic tap-changing gear. The foreseen layout provides for five further 30,000 kVA, 132/33 kV transformers and two further 132 kV incoming circuits from Laksapana.

The new circuit breakers will be of the small-oil-volume type.

Substations

There are four existing 66/33 kV substations each equipped with two 3,000 kVA transformers. Two substations are connected to the Colombo transmission line at Avissawella and Padukka, one at Norton and the fourth at Peradeniya. As at the power house and Colombo receiving station, the existing substation switchgear is of the bulk-oil type. Arrangements have been made to facilitate the addition of two further transformers in each substation when the growth of load warrants it. The 33 kV system, as mentioned earlier, is protected by arc-suppression coils at each substation.

The present contract provides for the construction of four more 66/33 kV substations, three of which, at Nuwara Eliya, Badulla and Kurunegala, will be equipped with two 3,000 kVA transformers and the fourth, at Bolawatta, with two 5,000 kVA transformers. The switchgear will be of the small-oil-volume type. Again, arrangements have been made for adding further transformers as the occasion demands. As has been stated earlier, two 66 kV transmission lines have been designed for later conversion to 132 kV and the two substations concerned, Kurunegala and Bolawatta, will have the equipment set at clearances suitable for the future 132 kV supply. Arc-suppression coils will again be installed in the 33 kV transformer neutrals at each substation.

The transformers in the existing and the new substations are designed with hand-operated on-load tap-changing gear and with a tertiary winding to provide a 400/230 V supply for the operation of the substation.

Distribution

In conjunction with the main scheme, 33 kV overhead lines were and are being provided for distribution from the main substations to subsidiary substations outside the Colombo area. Provision is being

Fig. 10. Penstocks for Stage II in course of erection

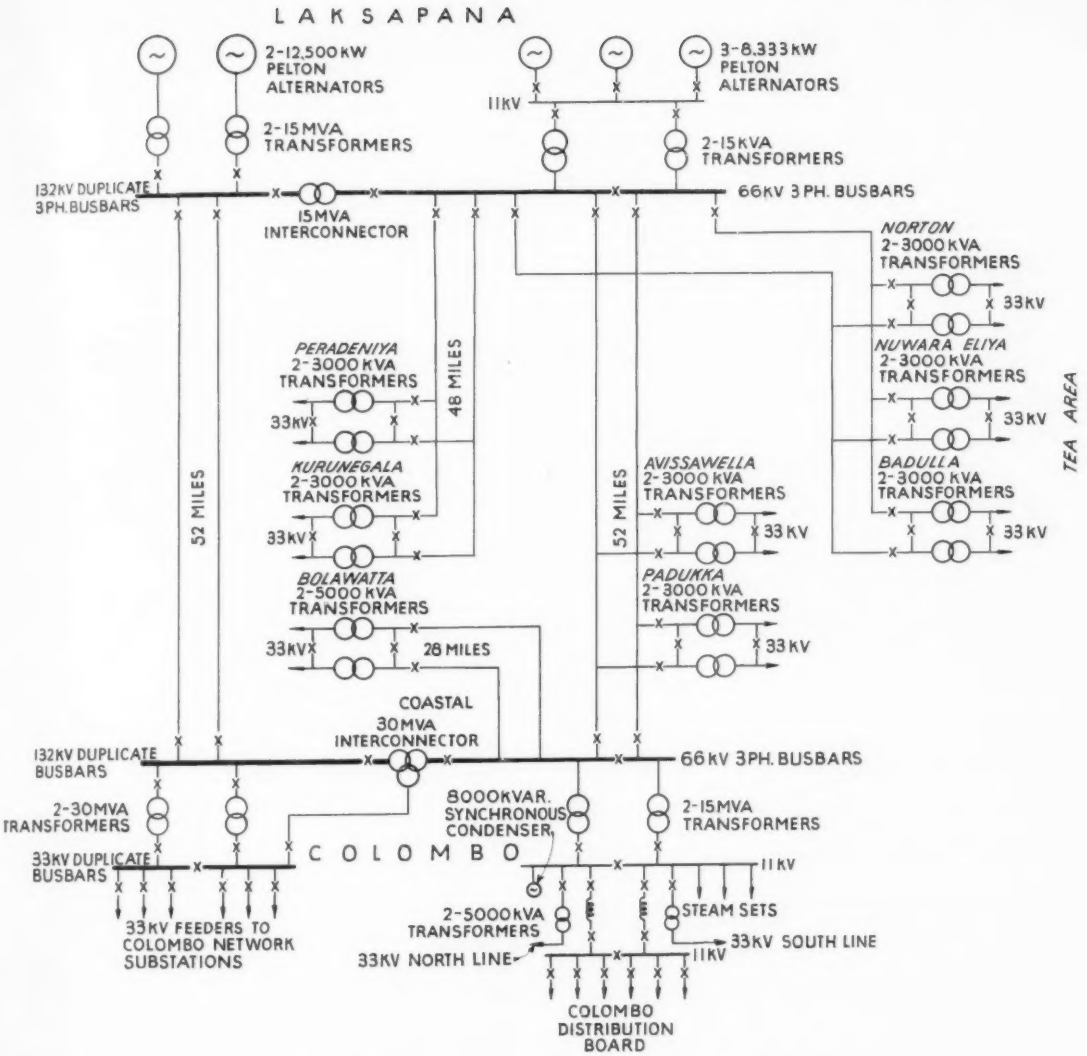


Fig. 11. Diagram of the electrical distribution system

made for the supply of 33 kV cables from the 33 kV switchgear in the receiving station to 33/11 kV substations to be established in Colombo town to supplement the existing 11 kV underground ring mains. Provision is also being made for the supply of additional 11 kV cables for connection from the 33/11 kV substations into the rings and for strengthening the rings where necessary. The 33 kV and 11 kV overhead distribution work outside Colombo and all low-tension facilities in and outside Colombo will be carried out under the responsibility of the Department of Government Electrical Undertakings.

Finance

The work under the present contracts is being financed by a loan made to the Government by the International Bank for Reconstruction and Development to provide the necessary foreign exchange for imported goods and services in the currencies of countries of origin. The loan covers not only the goods and services required for the present four main contracts but also those required for distribution, etc., including construction equipment and transport vehicles.

Engineering and Constructing

The Consultant Engineers for the hydro-electric scheme are Messrs. Preece, Cardew & Rider in association with Messrs. Coode and Partners. The contractors for the present Stage IIA of development are: Gruen & Bilfinger A.G. of Mannheim, civil-engineering work; Société des Forges et Ateliers du Creusot of Paris, pipelines; Le Matériel Électrique S.W. of Paris in association with Société des Forges et Ateliers du Creusot and Compagnie Général d'Énterprises Électriques, electrical and mechanical plant and equipment; Società Anonima Elettrificazione of Milan, transmission lines.

The contracts for the four sections of Stage IIA are due for completion in time for the new plant to be put into commercial operation towards the end of 1957.

Book Reviews

The Six-Inch Water Tunnel at the St. Anthony Falls Hydraulic Laboratory and its Experimental Use in Cavitation Design Studies. By Lorenz G. Straub, John F. Ripken, and Reuben M. Olson. Technical Paper No. 16, Series B. St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, Minnesota. Limited Distribution. Price $0·75.

This publication, which is intended for limited distribution, is a copy of the paper under this title presented at the International Symposium on Cavitation in Hydrodynamics held at the National Physical Laboratory in September 1955. It describes a recirculating model water tunnel which has been devised at the St. Anthony Falls Hydraulic Laboratory for the purpose of determining prototype design data for use in the planning of various types of cavitation test facilities. The test section of the model is 6 in. in diameter, and various boundary geometries have been studied in their relation to the test stream flow quality. Special emphasis has been given to the cavitation test limits imposed by the test section boundaries and various other tunnel components. The paper describes the basic tunnel, the critical cavitation tests made on the tunnel, and some cavitation studies made in the tunnel. Observations made on closed (cylindrical and diverging), open, and slotted-wall test sections are discussed. A minimum cavitation index of about 0·023 can be achieved in the diverging closed-jet test section at a velocity of 50 ft. per sec.

Some cavitation studies indicate how the cavitation susceptibility of the tunnel water varies, and show that the critical cavitation index of a slender body is more constant when based on a measured pressure than when based on vapour pressure.

Technologia betónu s osobitnym zretelom na vodné stavby (Concrete Technology, considered especially with regard to Hydraulic Structures), by Juraj Stork. Published by the Technological Section of the Slovak Academy of Sciences, Bratislava, 1954, 6·7 in. by 9·5 in., 2 vols., 1,124 pp., 132 photog. ill., 342 diagrams and graphs, 242 tables, 23 appendices. Price in Czechoslovakia Cz.Cr.245.—(about £12 5s. 0d.).

One may well wonder how a comparatively small country like Czechoslovakia can bring it about to print 1,500 copies of such a bulky work on such highly specialised subject matter. We understand however that the volume of concrete to be absorbed by hydraulic structures in the next ten years is assessed at 5 to 6 million cu.m., an unpretentious figure perhaps but it applies to Slovakia alone and does not take into account the requirements of Bohemia and Moravia. With the exception of the Vltava development, we know very little about Czechoslovak hydro-electric schemes, but if we look at a physical map of the country it is obvious that, in addition to contemplated Danube projects, Czechoslovakia still offers wide possibilities for further developments. Furthermore, there can be no doubt whatsoever that Czechoslovakia follows closely in the steps of the Soviet Union in scientific and technological studies, and this alone certainly justifies the publication of such a work in a country which, before World War II, boasted three Technical Universities, not to mention a fair number of technological schools. The work covers comprehensively all the aspects of the subject, from the properties of the various components of concrete and concrete mixes to batching, laboratory tests and control measurements. A special chapter is devoted to failures occurring in concrete, their investigation and remedying. The final chapter gives practical examples of the composition of the concrete used in some Czechoslovak, European and overseas dams. The official forms used for concrete tests reproduced in the appendices show how meticulous Czechoslovak concrete regulations are. The bibliography lists no fewer than 1,006 items, and the index which follows is very good. The author unquestionably knows his subject and it can only be regretted that the language makes the work so inaccessible to British readers. From the viewpoint of book production, the two volumes leave nothing to be desired. Some of the photographic illustrations are undoubtedly reproductions from other publications but are still quite good, and the diagrams are up to the highest standard.

Turbinnoe Oborudovanie Gidrostantsii (Turbines for Hydro-electric Power Stations), by Professor N. M. Shchapov, Doctor of Technological Sciences, State Prize Winner. Published by Gosenergoizdat (State Publishing Office for Energetics), Moscow-Leningrad, 1955. 8 in. × 10 in., 272 pp., 272 ff. Price in U.S.S.R.: Roub. 19.

This compendium on turbines, written by one of the foremost Russian specialists, is the first work of its kind to reach us from the U.S.S.R., and if Russian scientific and technological literature, taken as a whole, is up to the same standard, then let it be said that we, in the Western world, have not much to teach them. The work is obviously intended for students of technical universities and colleges of technology and as a textbook it could hardly be improved upon. Though written in fairly condensed form, it covers adequately all the aspects of the subject matter, from the fundamentals of theory to the manufacturing and testing of turbines. Just to mention a few of its 19 chapters, the sections on cavitation, losses in turbines, energy balance sheet, and automatic regulation are particularly noteworthy. A remarkable feature of its bibliography is that the 217 items listed, books or articles, are all by Russian authors. The book is well produced, print and illustrations being excellent. It can only be deeply regretted that the difficulty of the language makes this valuable addition to water-turbine literature so largely inaccessible to British readers.

Industrial Research, 1956-57. Advisory Editor, Percy Dunsheath. Todd Publishing Group Limited. Distributed by G. Harrap & Co. Ltd., 182 High Holborn, London, W.C.1. 444 pp. Price £3 3s. 0d. net.

This is the third edition of a reference book and directory covering the many British organisations and bodies concerned with industrial research. In the present edition there is a new section covering the whole of the activities of the United Kingdom Atomic Energy Authority. The range of research covered by this book extends far beyond engineering into such

fields as brewing, food, textiles, and seaweed, but hydraulics and civil engineering are apparently regarded as mainly outside its scope.

Annuaire de l'Association Suisse des Electriciens & Union des Centrales Suisses d'Electricité (Yearbook of the Swiss Association of Electrical Engineers and Union of Swiss Power Stations), published as a special issue of the Bulletin ASE, Zurich, 8 in. × 11¼ in., 136 pp. The 1956 issue of this yearbook contains, in addition to the usual directories and general information, a list of the rules and recommendations, as well as other publications, issued by the Association; these publications include an edition in English of the Swiss Rules for Hydraulic Turbines. A directory of the Electricity Sections of Swiss University Institutes and secondary technological schools is appended.

"Engineering News," Lahore. We have received the first issue of this new quarterly journal, published by the West Pakistan Engineering Congress at Gangaram Buildings, The Mall, Lahore. The publication of a journal devoted to engineering in West Pakistan was long overdue. There were many difficulties to be overcome and many formalities to be gone through before the first issue of the journal was out, just in time for the annual session of the Congress. To our congratulations to the West Pakistan Engineering Congress, we add our best wishes of success for their new venture. Annual subscription to *Engineering News* will be Rs. 5s., foreign postage extra. Single issues, when available, can be supplied at Rs. 2s. each.

Grund- und Wasserbau in praktischen Beispielen (Foundation and Water Engineering in Practical Examples), by Professor Dr.-Ing. Otto Streck. Vol. I, 2nd Edition, revised. Published by Springer-Verlag, Berlin-Göttingen-Heidelberg 1956; 6 in. × 9 in., VIII-416 pp., 251 ff. including a folding plate.

The first volume of this well-known work, which covers foundation engineering, hydrostatics and ground-water flow, was first printed in 1943 and now reappears in a revised and enlarged edition. Part I is devoted entirely to foundation soils. Following a short introduction on the dependence of structures on their foundation ground, the author briefly describes the formation and subsequent transformations of geological strata and, under the heading "Soil: the Engineer's Foe," reviews typical instances of heavy damages to structures caused by movements of the foundation soil. Not to mention the classical example of Pisa's famous leaning tower, several instances of damage to dams are included. The various kinds of foundation soils are then surveyed, and considerations on soil investigation conclude the theoretical section of the volume. Part II, comprises 17 well selected practical problems, for which solutions are worked out in detail; most of these problems are applicable, at least in part, to structures connected with hydro-electric developments. Problem No: 10 (p. 285) deserves special attention, since it consists of no less than 25 pages devoted to the mathematical computation of the cross section of a gravity dam by means of E. Linck's method of the basic triangular section, and proceeding from the forces intervening in the structure instanced and other conditions of stability. The cross section arrived at by calculation is then checked graphically (ff. 180 and 181, p. 304). We should also like to single out problem No. 1 which takes in all the fundamentals applying to the closing by sheet piling of a construction pit for a large hydraulic structure—water and earth pressures at various levels, depths to which piles are to be rammed under determined conditions, etc. An appendix of 14 tables completes this range of problems, the study of which will prove beneficial to practical engineers and students alike. The bibliography inserted between Parts I and II is restricted to German literature published in recent years. The index at the end of the volume is particularly good. As in its first edition, Professor Streck's work remains not only an excellent textbook but also a most useful reference work.

Swedish State Power Board Publications. The Swedish State Power Board is producing a most useful series of publications, known as the "Blue-White Series," in Swedish and English editions, discussing technical achievements in the field of power production and transmission. Recent titles include "High-Voltage Transmission Developments in Sweden," "Bundle Conductors meet all Swedish Requirements," "An Atomic Power Programme," and "The Gotland H.V. D.C. Transmission Link." A Swedish title in this series reprints a lecture given by Åke Rusck, President of the Swedish State Power Board, on the question of an integrated power supply in Denmark, Norway and Sweden.

Pirelli-General Cables for Snowy

Pirelli-General Cable Works Ltd., an associate of The General Electric Co. Ltd., has been successful, through The British General Electric Co. (Pty). Ltd. of Sydney, in obtaining the contract for the manufacture in England and the installation in Australia of approximately 3,500 yards of 330 kV single-core ·325 sq. in. copper-conductor oil-filled lead-sheathed cable for the T.1 power station at Cooma of the Snowy Mountains Hydro-Electric Scheme.

The cable contract includes the design and manufacture of seven 330 kV single-phase cables for 340 amperes, grouped in two three-phase circuits with one spare cable, complete with terminations, supporting structures and all ancillary equipment. These will be the first 330 kV oil-filled cables manufactured in this country, and follow the two supply and installation contracts carried out by Pirelli-General for 301 kV oil-filled cables for Kemano.

Dominion Water Turbines. No. 1, 1956, of the *Dominion Engineer*, the house journal of Dominion Engineering Co. Ltd., is devoted to "Highlights of 1955," and the section dealing with the Hydraulics Division reveals some impressive achievements. Illustrated in this section are one of four 18,500 h.p. propeller runners for Manitou Falls, three of six 88,000 h.p. impulse runners for Cubatao, two 56,000 h.p. Francis runners for Peixoto, one of four 35,000 h.p. Francis runners for Whakamaru, the runner and shaft assembly for the twelfth 105,000 h.p. turbine for Sir Adam Beck No. 2, a 150,000 h.p. impulse wheel for Kitimat, and runners for the Rapid Blanc and La Tuque plants of the Shawinigan Water and Power Company.

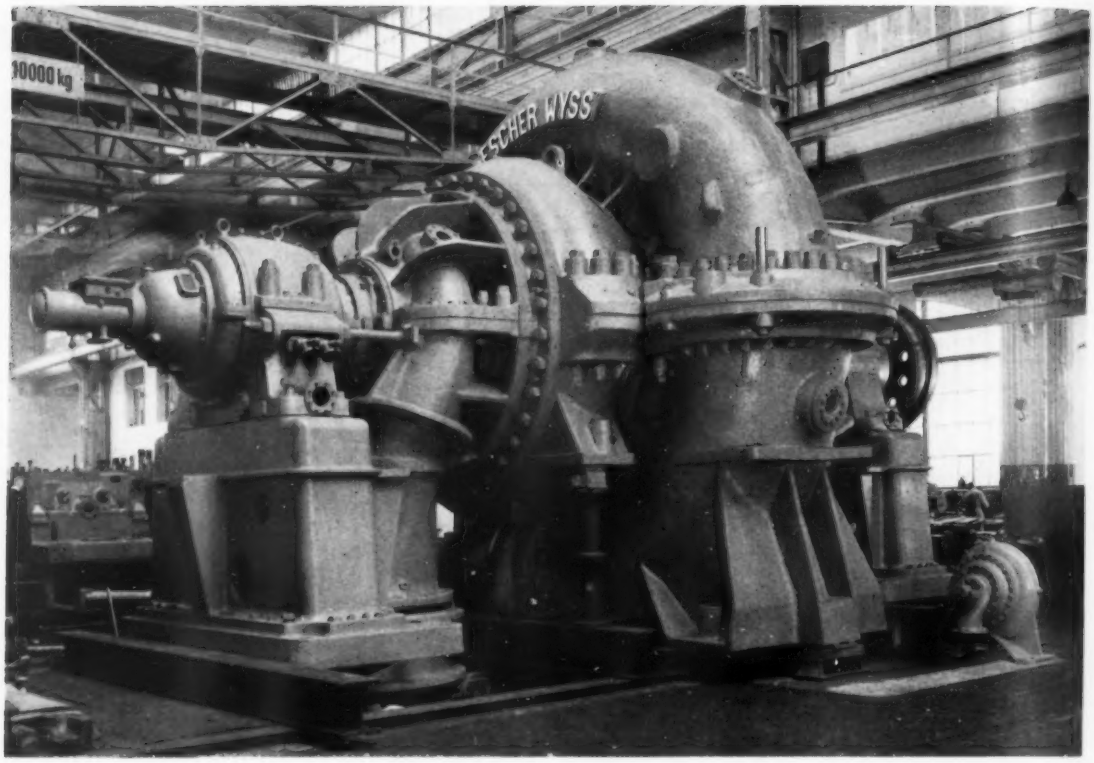


Fig. 1. One of the Limberg pumps in the Escher Wyss works. The model test pump is on the floor to the right of the picture

The Limberg Storage Pumps

by A. PFENNINGER

ONE of the most important pumped-storage installations in Europe is the upper stage of the Glockner-Kaprun development in Austria, owned by Tauernkraftwerke A.G. Details of this scheme were given in an article published in our August and September 1954 issues, and a diagram of the upper stage is given in Fig. 2. The highest storage is formed by Mooserboden reservoir at an elevation of 2,035 m., and a contribution to this storage is made from Margaritze reservoir at 2,000 m. through an underground pumping station at Möll. An intermediate reservoir—the Limberg or Wasserfallboden reservoir—has been formed at a storage level of 1,622 m., and it is the head between the Mooserboden and the Limberg reservoirs which forms the upper stage of the scheme. The lower stage utilises the head between Limberg reservoir and the Kaprun power station, which lies at an elevation of 781 m. at the turbine nozzles.

Limberg power station, which is a reinforced-concrete structure monolithic with Limberg dam, can alternatively generate power by drawing on the Mooserboden storage, or in times of off-peak demand and of excess flow into Limberg reservoir, it can pump water from Limberg to Mooserboden for use at times of peak load. For this purpose it is equipped with two combined pumping and generating sets, each comprising a turbine, motor/generator machine, braking turbine, toothed coupling, and storage pump. The arrangement is shown in outline in Fig. 2 and is seen in greater detail in Fig. 3. Fig. 2 also shows the system of pipes and valves allowing for turbine or pump operation at will. This system, however, is even more flexible than is apparent from a first inspection, for it is possible partly or fully to short-circuit the pump and turbine hydraulically in order to use the set for frequency regulation. Furthermore, the electrical machine can be operated as a synchronous condenser, the pump being disconnected and the turbine running empty.

For these two sets Escher Wyss Limited, Zurich, have built what are claimed to be the largest storage pumps ever to be constructed outside the United States, and one of these units in the makers' works is depicted in Fig. 1. The turbines and braking turbines were built in the Escher Wyss works at Ravensburg.

The turbines, which are of the horizontal Francis

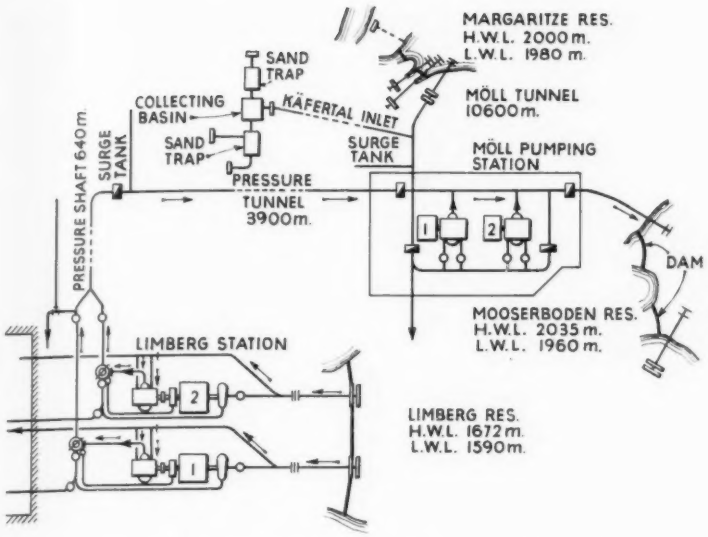


Fig. 2. Diagram of the Glockner-Kaprun upper stage

type, can each develop 59,000 kW at 500 r.p.m., under a head of 364 m., but are limited to 56,000 kW in accordance with the prevailing operating conditions. They are overhung but are so coupled that either the turbine or the electrical machine can be removed without disturbing the other. Compressed air is used to evacuate the turbine and draft tube, and a shut-off valve isolates the turbine from the draft tube, which extends horizontally through the dam into the reservoir. The bearing between turbine and generator can accept a thrust of 116 tons in either direction.

The braking turbine is introduced to shorten the time required for changing over from pump to turbine operation and *vice versa*. When the set has almost reached a standstill the toothed coupling which connects the pump to the generator is engaged by a servomotor, located at the far end of the pump and acting through the bore of the pump shaft.

The two storage pumps are of the two-stage double-admission type, and each is provided with two single-stage steel impellers feeding their respective flows to a central cast-steel double impeller which delivers to the spiral. The rotor on the Escher Wyss stand at the recent Basle Fair is seen in Fig. 4.

The inlet branch, with an inside diameter of 1,350 mm., the overflow castings and the multi-part spiral are steel castings delivered by Schoeller - Bleckmann and machined in the works of Maschinenfabrik Andritz. The impellers, likewise from the same foundry, were machined in the Zurich works of Escher Wyss, where the remaining parts, such as shaft, coupling, etc., were also finished.

The pump is split horizontally so that during erection the rotor can be inserted complete. Here too the labyrinth rings, which of course are subject to wear, are inserted separately, so that they can be replaced without difficulty. At the free end of the pump is the axial bearing designed to take up the remaining thrust, up to about 100 tons in either direction.

For the pump glands a device has been introduced for the first time which permits all the separate parts to be checked or removed without the pump having to be emptied. This is of particular importance in view of the high inlet pressures that can obtain.

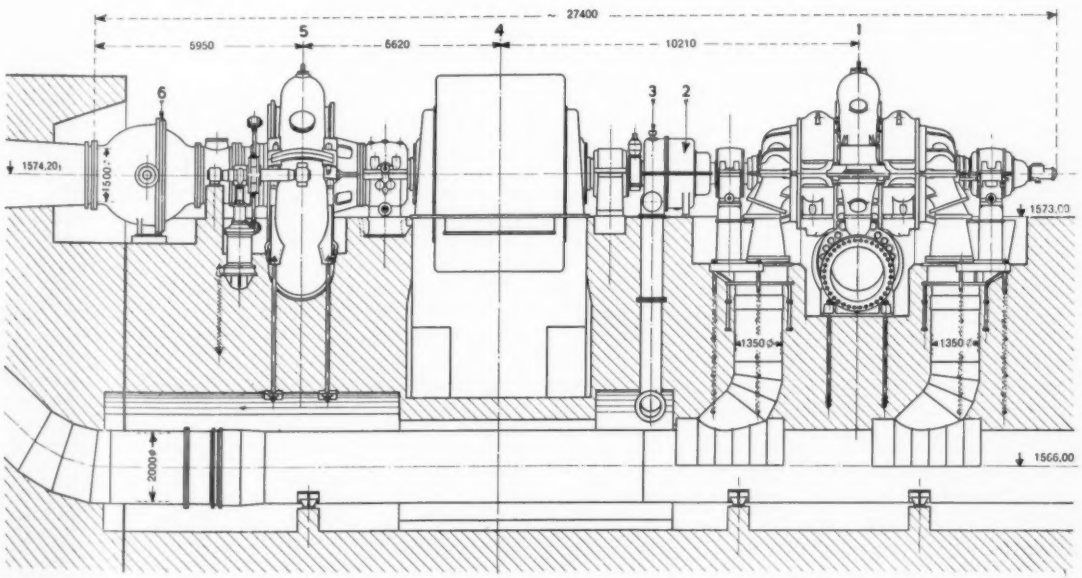


Fig. 3. Arrangement of turbine-motor/generator-pump set

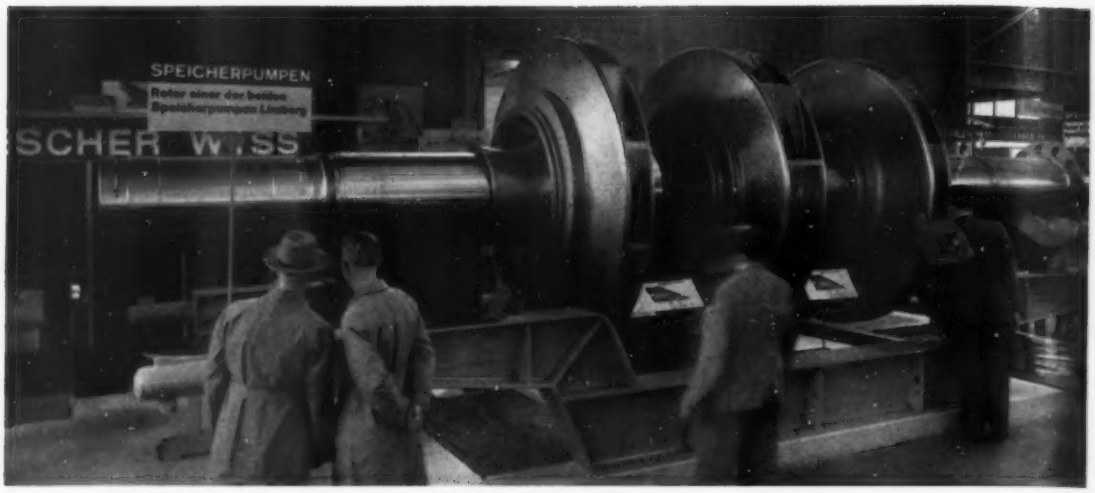


Fig. 4. A pump runner exhibited at the recent Basle Fair

The shaft, which is about 8 m. in length, has a diameter of 820 mm. where the double impeller is fitted, and tapers off towards the bearings where it is approximately 600 mm. The distance between bearing centres is 7.450 mm. The overall length of the storage set is 27.4 m.

Exhaustive model tests were necessary to determine the design of the pumps, for the wide range of operation arising from the variations in the levels of the Mooserboden and Limberg reservoirs presented somewhat exacting conditions, and it was not easy to procure a pump characteristic that would cover all the requirements. The level of the Limberg reservoir fluctuates to the extent of 82 m., resulting in an inlet head on the pumps ranging from 15·8 to 97 m. In the Mooserboden reservoir the level fluctuates to the extent of 75 m. In all, the pumps had to be designed to operate against a range of delivery head from 320 to 420 m., the water quantities involved ranging from 11·6 to 16·6 cu. m. per sec. and the inputs from 53,400 to 62,700 kW. No less than three sets of impellers were tested on the model in order to determine the most satisfactory design, but by means of these tests it has been possible to secure complete information regarding all operating conditions.

To provide assurance against fluctuations in the network it was a condition that operation shall be maintained between 48 and 52 cycles with due consideration of the geodetic conditions of level on the one hand and the maximum possible input on the other hand. This called for a corresponding course of the Q/H line and in addition a good efficiency over the wide operating range. It was possible to meet both these requirements with the aid of the model tests. With a scale of approximately 6·7 the efficiency curve of the model attained an optimum of 86 per cent., which may be considered satisfactory with the specific speed of the impeller of 85.

Apart from the tests with water referred to above, detailed investigations by the aerodynamic method on the equally important guide vanes revealed the influence of the vane angles and inside width on the characteristic line and efficiency of the pump. Intermediate pressure measurements on the model pumps over the whole operating range provided data as to the effect of the changes of direction after the first stage and the behaviour of the double impeller with the subsequent energy conversion in the spiral. By means of these measurements of the flow, from the inlet to the outlet of the pump, it was possible to reduce the losses that were determined and thereby to raise the efficiency.

The danger of cavitation for the range of low inlet heads similarly had to receive careful consideration. During these trials it was possible to prove quite clearly, for example, that with considerably varying pressures in the two inlet branches of the pump—which however need hardly be feared in such a large unit—the double arrangement of the impellers adopted by Escher Wyss for a considerable time ensures absolutely reliable operation. The advantage of this design lies chiefly in the fact that impellers of higher specific speed and of better efficiency can generally be adopted, and as a consequence of reduced lateral impeller friction a further increase in efficiency results from the double impeller. The thrust bearing, which has to be designed for the full thrust in cases where the impellers are arranged in sequence, only has to take up a certain residual thrust in an arrangement as referred to above.

In view of the possibility of the network being interrupted or of some wrong manipulation being made to one of the many valves it is of great importance in such a large installation to have full knowledge of the pressure surges thus created. The data for making these calculations were obtained from a further series of trials over the respective ranges of braking and turbine operation. For this purpose the model pump was measured on the one hand as a brake and on the other hand as a turbine in such a manner that the pressure-surge calculations were rendered possible for about 14 operating cases.

This large number of calculations in respect of pressure surges was connected on the one hand with the layout of the whole pipework and the valves needed, and on the other with the co-operation with the Möll pumping station. Four rotary valves, four butterfly valves and the safety sluices of the Limberg dam were

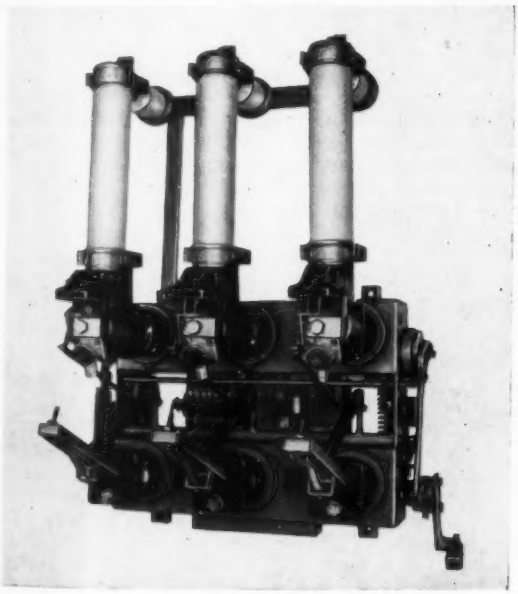
manufactured in Austria according to workshop drawings of Escher Wyss.

ASEA Auto-Pneumatic Circuit Breakers

The ASEA organisation has placed on the market a new auto-pneumatic circuit breaker known as type HRBUA 10/200. It consists of a normal circuit breaker type HRBA 10/400 which has been fitted with built-on fuses of type SHPB, and is designed for 6·6—11 kV with fuse ratings up to 200 A. The circuit breaker itself has a closing capacity corresponding to a short-circuit power of 300 MVA at 11 kV (it can be closed against a peak value of 40 kA), while the breaking capacity depends on the rated current of the fuses. The lower the rated current, the higher the breaking capacity.

The high closing capacity has been obtained by means of a quick-closing device; a closing spring mounted in the circuit breaker is first cocked as the handle is moved and then automatically released, closing the circuit breaker with great force. Because of its quick closing action, this type of circuit breaker is also suitable for synchronising.

The operating gear of the circuit breaker is available in different designs—either for hand or for motor



ASEA auto-pneumatic circuit breaker

operation. The motor operating gear can also be used for auto-reclosing.

The circuit breaker is mainly intended to be used in installations where the normal load is low but the short-circuit current is fairly high, where three-phase breaking is desired and fuses alone do not suffice, and where a power circuit breaker of adequate size would be too expensive. In this case, the auto-pneumatic circuit breaker itself is only used for breaking the normal load current, while the fuses function as overcurrent and short-circuit protection.

Super-Grid Transformer Tests

The destructive effect of lightning strokes and surges on electrical transmission systems and equipment has made the study of the phenomena, and the solution of the many problems arising from it, more and more urgent in view of the growing tendency to transmit bulk power at increasingly higher voltages. Great progress has been made in recent years in the collection of data on the behaviour of lightning on transmission systems, and high-voltage research and study of insulation strength problems on the transformers used in conjunction with these systems have reached a point

One phase of Bruce Peebles 120 MVA 275/132 kV auto-transformer on test

where the largest power units can now be built to withstand the severe conditions.

Bruce Peebles & Co. Ltd., Edinburgh, recently invited a large party of prominent electrical engineers to witness impulse tests on a full-scale prototype of one phase of a 120 MVA 275/132 kV 3-phase auto-connected transformer, four of which—all with on-load tap changing switchgear on the 132 kV terminals—are on order for the South of Scotland Electricity Board for Clyde's Mill substation. The specified impulse level of 1,050 kV did not present difficulty in demonstration since ample high-voltage testing plant is available at the company's works, and the tests were carried through without a hitch. The testing arrangements are shown in the picture. The prototype transformer is seen in the foreground and behind it the sphere gap and the 1,875 kV impulse generator. The type tests comprised the application of full-wave impulses at 525, 790 and 1,050 kV, followed by two chopped-wave impulses at 1,210 kV and in turn by two further full-wave shots at 1,050 kV. The level and the sequence of tests is that recognised as the British Standard; the wave shape throughout was the standard 1 × 50 microsecond.

Having withstood these tests successfully it was decided to submit the prototype transformer to a series of successively higher-voltage tests until possible eventual breakdown, and the 275 kV winding was sub-

jected to more than 70 impulses ranging uniformly from 1,050 kV full wave up to 1,660 kV chopped wave without breakdown or any signs of serious weakness.

These tests, apart altogether from showing that the design of the transformers provided adequate safety margin for any conditions they are likely to meet in service on the 275 kV super-grid, demonstrated that the arrangement of disc-type high-voltage winding used on the prototype, a construction which is recognised as the strongest mechanically, will be entirely suitable for use on transformers for systems operating at 330 kV and 380 kV.

Abstracts from the World Technical Press

Record Span Across Norwegian Fiord

The record of the Messina Straits line, linking Sicily with the Italian mainland, has now been beaten by 400 ft. by the three-mile transmission span running from Rabnaberg to Fatlaberg to the north, across one of western Norway's largest fiords. The position of the span was selected after careful investigation and consideration of all factors; available shorter crossings would have been exposed to snow slides. The power line transmits at 60 kV but its insulation was specified for a later increase to 150 kV. Horizontal lengths of the lines are as follows: Phase 1, 15,872 ft., phase 2, 15,847 ft., phase 3, 15,951 ft., spare line, 16,036 ft. Average height of dead-end tower sites is 1,575 ft. at Rabnaberg and 2,560 ft. at Faltaberg; free height of line above highest water level, 225 ft. Owing to ground conditions, distances between phases vary between 138 and 213 ft. The towers, built on the site, are reinforced-concrete three-legged pylons. Fatlaberg's first pylon was poured on June 29 and its fourth on July 29, 1955, each whole pylon being poured in one day. Rabnaberg's pylons were poured from August 2 to 27. Sand, gravel and concrete were made at each pylon, and the reinforcement was Brinell tested. The pylons were not exposed to stress until 28 days after pouring. The line was delivered from White Cross Co. Ltd., England. A description of the Messina Straits 220-kV line concludes this article. (*Electrical World*, Vol. 145, No. 20, May 14, 1956, p. 100, 2 ff.)

Paving a River Bed

Piers are a feature that bridges and run-of-river hydro-electric developments have in common. The procedure described in this article could therefore easily be applied to weirs or other structures under similar conditions. In July 1955, the swift current of the Fraser River at Mission, B.C., undermined a combined railway-highway bridge pier, causing a 150 ft. steel bridge section to fall into the stream. Canadian Engineers have now tamed this fierce river by paving its bed across its full width and for a distance of 100 ft. downstream and 60 ft. upstream of the bridge site. The paving consists of 11 ft. square slabs of reinforced concrete, 10 in. thick, that were put down by divers. To meet the possibility of the river scouring away the mud on the downstream edge of the mat, and undermining it, 100 ft. square brush mattresses, 3 ft. thick, were fashioned in layers, plywood-like, and laced with wire; these mattresses were then floated to the proper location and weighted on their leading edge with steel rails and stones, thus sinking into position. To give the pier a solid foundation, forty-three 72 ft. steel piles were driven into the river bottom. Around these, a steel cofferdam was erected, into which went 1,400 cu. ft. of concrete. After 225 tons of twisted steel had been removed from the river, the scour holes were filled with rock, whereupon the concrete floor was laid. The main cause of the collapse of the bridge was a 90 ft. deep hole adjacent to the pier. (*Engineering News-Record*, Vol. 156, No. 18, May 3, 1956, p. 70.)

Investigating Piping in Earth Dams

Both Bligh's and Lane's empirical methods were worked out in conjunction with the investigation of the foundations of massive dams, and thus apply to such dams. Nevertheless, similar methods are advocated for earth dams in two works on dams published as recently as 1954 by Mallet & Pacquand in France, and Keil in Germany. The author discusses the formulae advocated by Bligh and Lane, and examines the possibility of extending their validity to earth dams. Empirical formulae and theoretical processes may be quite useful at the outset, when determining the dimensions of a structure and the measures to be taken against the danger of piping, but their results must be checked by measurements on site. If such measurements are taken in time, they will show the actual progress of piping while the dam is still in course of construction, and it will be possible to apply the necessary remedial measures. (Dr.-Ing. Siegfried Dyck, *Wasserwirtschaft-Wassertechnik*, Vol. 6, No. 4, April 1956, p. 108, 5 pp., 6 ff., 4 tables.)

Underground Storage Powers a Surface Plant

At the Miègebat plant, French Pyrénées, we have the instance of an underground stream being harnessed to a surface power house (WATER POWER, May 1953, p. 197). Still greater violence is being done to the natural order of things at the Sainani plant on the Zongo River, Bolivia, which receives its supply of power water from a man-made underground storage facility. Sainani is the fifth step in a chain of hydro-electric plants built on the Zongo River for the Canadian-owned Bolivian Power Company. The chain begins at a headwater reservoir near the Continental Divide and proceeds downstream without any additional annual flow regulation, but at Sainani, while the four upstream steps are fed by canals diverting water from the Zongo River and tributaries, about 1½ miles of tunnel, driven from ten adits, will carry the discharge from the upstream Santa Rosa plant to the 900 ft. drop at the Sainani plant. Midway in this stretch of unlined tunnel, tunnel workers are hewing out of solid granite, at right angles to the tunnel, a forebay 230 ft. long by 26 ft. wide and 26 ft. high that will have a capacity of 155,000 cu. ft. for peak power generation to supply fast-growing, two-mile high La Paz. A control chamber, also hewn out of the solid granite above the subsurface forebay, will direct the flow of 105 cusecs of water from the tunnel into the

forebay or into the pressure tunnel leading to a 40 ft. diameter steel penstock. Tunnel work, which began in April 1955, was virtually completed by April 1956. A few short reaches of tunnel and the portals will have to be concrete lined. Owing to the absence of natural sand and gravel in the region, aggregates are made by hand crushing the granite from the tunnel excavation and sieving it at the site. The result is a harsh concrete mix next to impossible to finish smoothly and costing 290s. per linear foot of tunnel lining at the present rate of exchange. The conventional surface power house will contain the biggest generator in the country—an about 11,000 kVA unit driven at 500 r.p.m. by two Pelton type turbine wheels. The combined turbine and generator weight is about 105 tons, which will have to be transported over a single-lane switchback mountain road from the railhead at La Paz; for this purpose, Bolivian Power Company bought a short-wheel-base truck driven by a 450 h.p. diesel engine that can haul a maximum load of 30 tons on an 18% gradient. At the plant site, the penstock and other pieces of machinery and equipment will be taken across the Zongo River by cableway. Power from the new plant will be put on the line by September 1956. Chief Engineer Carlos Munoz Roldan, who is in charge of construction for the Bolivian Power Company, points out that the Zongo River is only one of hundreds of similar streams with excellent hydro-electric possibilities that are close to load centres. (A. E. Niederhoff, *Engineering News-Record*, Vol. 156, No. 18, May 3, 1956, p. 67-70, 1 f.)

Sealing Roxburgh Dam Site

A detailed description is given of the work done to seal the upstream end of the foundation area of the dam at Roxburgh, New Zealand, using sheet piles. The decision to adopt this procedure was arrived at after three months of considerable difficulties. The idea of working both ends of the foundation area simultaneously had to be abandoned, owing to manpower shortage and limited capacity of pumps. However during the next 60 days, the upstream end of the river gullet was completely sealed off, and the downstream end tightened to such an extent that excavation down to the bottom could proceed, involving a total of 20,000 cu. yards. A subdivision wall was built by the end of May 1955, and by June 20, 1955, the whole gullet was filled, using modified concrete. In a 10-day continuous pour, 15,000 cu. yards of this concrete were poured and, with it, the foundations of the last three blocks became available in time to maintain the high concrete output, i.e., before other blocks reached their final height. This was the first time that fly-ash was used in New Zealand to modify the normal concrete to a low-heat type, and the 15,000 cu. yards poured in one single operation presented no difficulties to the heat of hydration control. The sheet piles used were Larssen No. 3. (R. J. J. Pfenniger, Dipl. Ing. E.P.F., *New Zealand Engineering*, Vol. 11, No. 3, March 1956, p. 68-70, 13 ff.)

Earth-Dam Control

This is a reprint of a paper presented to the second Australian and New Zealand Conference on Soil Mechanics and Foundation Engineering. The paper deals with the rapid determination of moisture content and its influence on earth-dam control, and is divided into two parts. Part I gives the reasons for developing rapid methods of determining moisture, and investigates their influence on control methods. Statistical theory is used to show that, for the placed material to conform with usual design limits, close control of the moisture content in the borrow areas is essential. Part II details the methods considered and the reasons for adopting water displacement reaction with carbide and rapid drying as the three methods for intensive investigation. The results show that field moisture contents with accuracies of the order of 0·2% moisture can be obtained, using properly designed equipment and semi-skilled operators. Of the three methods of investigation applied, the rapid-drying method is probably capable of providing the greatest rate of determinations per observer, but the carbide method has the advantage of giving very reproducible results and not requiring any electrical equipment to operate it. (J. D. Hodgson (Part I); R. G. Wylie, A. G. Douglas and A. F. A. Harper (Part II), *New Zealand Engineering*, Vol. 11, No. 3, March 15, 1956, pp. 71, 4 pp., 7 ff.)

Excavating Kiewa Pressure Shaft

This article describes how the excavation of No. 4 pressure shaft at Kiewa Development, Victoria, was carried out. The pressure shaft connects the downstream end of the headrace tunnel at RL. 1,680 with a short tunnel leading to the turbines. It consists of a steel pipe of 13 ft. 6 in. internal diameter, set in concrete in a shaft declined at 50 deg. 30 min., and 600 ft. in length on the underlay. After careful investigation of rock conditions, it appeared that, if a large opening would not remain open safely for a long time, there were still excellent chances of the shaft remaining safe for a limited period; it was therefore decided to excavate the shaft unlined. Another factor in favour of this procedure was that the worst ground was toward the bottom of the shaft and would, therefore, be ultimately lined earlier than its upper sections. A pilot winze 8 ft. by 6 ft. was first sunk; this size was adequate to accommodate the necessary plant and services, and the winze was placed to one side of the final excavation, its collar being timbered with 6 in. by 6 in. cribbing raised 18 in. above the general floor level of the headrace tunnel and surrounded by concrete to form a waterproof wall. An electric single-drum 15 h.p. winch was installed, with a headframe consisting of a simple timber structure carrying the rails which allowed automatic dumping of a 3/4 cu. yard skip into 6 cu. yard tunnel trucks; these trucks stood on a spur off the main tunnel line. During the sinking of the winze, the power-station area was opened up by a shaft and inclined adit located about 450 ft. from the bottom of the pilot winze. This section was driven as an 8 ft. by 8 ft. pilot from the adit to meet a 7 ft. by 5 ft. pilot driven from the bottom of the winze. For this work, the skips were enlarged to 1 cu. yard capacity and fitted with end doors, similar to small mine trucks used for hand tramming. When the full skip was on the haulage rope and a few feet up from the bottom of the incline the latch was knocked clear. The angle of the winze allowed hoisting to proceed without spillage and in the tipple the door swung clear to allow tipping. For the section from the adit, 3 cu. yard granby trucks were used, and as soon as the tunnels connected, they were stripped to 15 ft. diameter, and the dirt removed

via the adit. As soon as this work was completed, the bottom was cleaned up and rails were laid set in concrete to carry the final steel lining. At the same time, the inclined winze was stripped to full size. Once stripping was completed to the top of the shaft, an Eimco 21 loader started loading out from the bottom, the muck being removed through the power station in 2 cu. yard side tippers into the tailrace, where level haulage in 6 cu. yard trucks was then available. As the rock was lowered in the shaft it was followed down by a crew who barred down the walls and back, cleaned out crevices in the bottom and laid permanent 45 lb. rails which were subsequently concreted in place. The barring down was made easy by the use of a special platform of local design which became known as the "Flying Saucer" and later the "Soup-spoon." This platform overhung the rail, allowing rock to fall clear of the work below; its handrail was a template and wherever rock protruded inside the minimum clearance line, it was removed by popping. When the rails reached the section of the winze which had required support, it was found that a soft fault zone had dribbled away, leaving a substantial cavity at the back, and the dyke rocks nearby were in a bad condition. The position was remedied, and absolute safety achieved, by building a form on skids in the headrace tunnel near the shaft collar. The form used was assembled around tunnel sets mounted on two long 10 in. by 10 in. runners. Lagging was then bolted to the sets which were suitably braced. The whole structure was then lowered into place and tied off to heavy pins. Concreting was done from the bottom, so the form and men were protected from falling rock by a heavy bulkhead which was also built in the headrace and lowered into place. No risks could be taken with men working up to 600 ft. below, but it was undesirable to have to place further concrete lining, and systematic roof bolting was adopted, supplemented by a heavy welded reinforcement mesh (3 gauge steel on 6 in. centres) and, where the rock was closely jointed, additional wire netting. (R. Ian Rankin, *Chemical, Engineering and Mining Review*, Vol. 48, No. 5, February 10, 1956, p. 151, 7 pp., 10 ff.)

Soviet Turbines

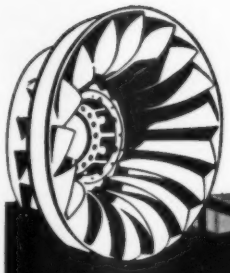
From an article written by the chief hydro-turbine designer of the Stalin Metal Works, U.S.S.R., we learn that Soviet turbines are now standardised in capacities ranging from 1,000 to 125,000 kW, all large stations having a uniform layout in which standard sections and parts are used. This, it is claimed, has greatly shortened the time required for designing, manufacturing, the production of ancillary equipment, and helping to improve quality. Particularly difficult problems were encountered at the designing and manufacturing stage of the vertical Kaplan-type turbines intended for the 2,100,000 kW Kuybyshev station. Each turbine is required to cope with a discharge of 700 cu. m. per second at a head of 20 to 30 m. A few dimensions of these 126,000 kW units give an idea of their gigantic size: turbine ring 14 m. diameter; runner with its adjustable blades 9·3 m. diameter; overall height of a complete generating unit 40 m., and weight over 3,000 tons. Nine of these turbines have already been completed and some of them will be put into operation this year. Soviet engineers are now busy designing turbines two to three times larger in capacity without exceeding the dimensions of previous record units. Among the latest plants commissioned in U.S.S.R., this article mentions Ust-Kamenogorsk, on the Irtisk River, which supplies the Altai Territory with electricity; Mingechaur on the Kura River in Azerbaijan; Tsimlyanskaya, on the Volga-Don Canal, and the Kama station. (N. N. Kovalev, *Indian Journal of Power & River Valley Development*, Vol. V, No. 11, Nov. 1955, pp. 15 and 24.)

Cloud Seeding Boosts Output

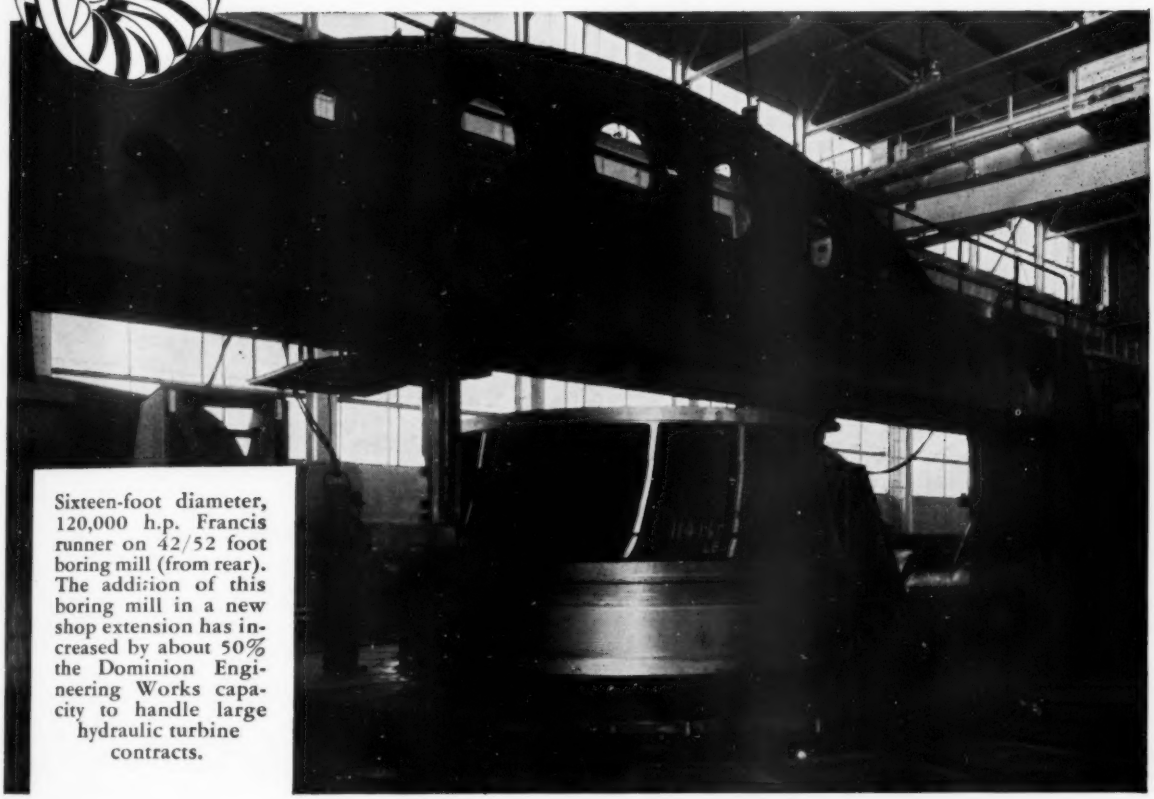
Two years of cloud-seeding operations carried out in the Rio Alberche watershed point to conclusive results. The actual stream flow, compared with the expected run-off from the river, indicated an increase of 64 per cent. in the first year and 12 per cent. the second. The Rio Alberche watershed, which has been a target for cloud seeding longer than any other area in Spain, encompasses 800 sq. m. of mountainous country north of Madrid, and provides power water to the chain of plants, 82,920 kW in aggregate capacity, operated by Union Electrica Madrilena. A continuously manned weather-reporting centre at Barajas Airport in Madrid is linked with 59 field stations to the west and south along lanes of prevailing moisture-laden southwest winds and, as soon as a storm is forecast and actually develops, Spanish field personnel at the stations whip silver-iodide smoke generators into action. Cloud-seeding for stream-flow improvement is one of six parts of a programme started by Water Resources Development Corporation, Denver, Colo., in October 1952. Two other phases cover the Rio Juvar and the Rio Tajo watersheds to provide increased stream flow for agriculture. (Irving P. Krick, Water Resources Development Corp., *Electrical World*, Vol. 145, No. 25, June 18, 1956, p. 24, 3 pp., 3 ff.)

Lining the Bersimis Power Tunnel

This survey of the work in progress at the Bersimis development of the Quebec Hydro-Electric Commission includes a description of the method applied to the concrete lining of the 7·5 mile power tunnel. The arch and sidewalls are poured first to a minimum thickness of 18 in. The concrete requirements are very tricky; the mix must have a fast rate of early set against cold rock of the tunnel, as the forms are stripped after a period of only 11 hours to be used again in a 24 hour pouring cycle. All concrete is produced at a central plant, some of the hauling distances being as much as eight miles. Trucks enter the tunnel through an adit, ride up a ramp at the particular work site, turn on a turntable, and dump into receiving hoppers through a grillage intended to give the concrete a certain amount of remix. The hoppers charge three pneumatic concrete placers which "gun" the wet concrete through 6 in. pipes overhead of the tunnel liner forms to a box at the rear form. From this box, concrete runs off both sides to fill the side wall, and eventually the whole arch. As the arch fills, the pipes are shortened and pouring is continued back toward the end of the forms nearest the concrete placers. There are 320 ft. of non-telescoping steel forms in use (in 5 ft. sections). Pours are made in 80, 120 and 160 ft. lengths. The whole concreting operation is performed by track-mounted jumbos, of which the longest measures no less than 280 ft. in length. (Arthur Fox, Jr., Associate Editor, *Engineering News-Record*, Vol. 155, No. 20, Nov. 17, 1955, p. 34, 6 pp., 10 ff.)



IN CANADA AND NEW ZEALAND...
IN BOLIVIA AND BRAZIL...



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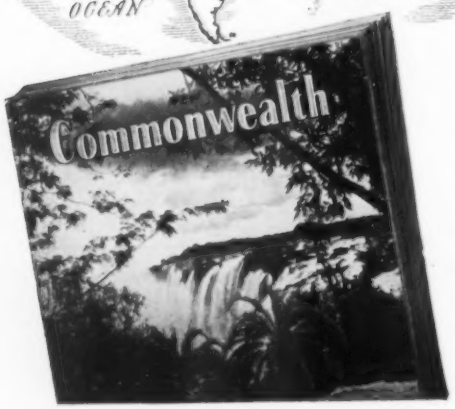

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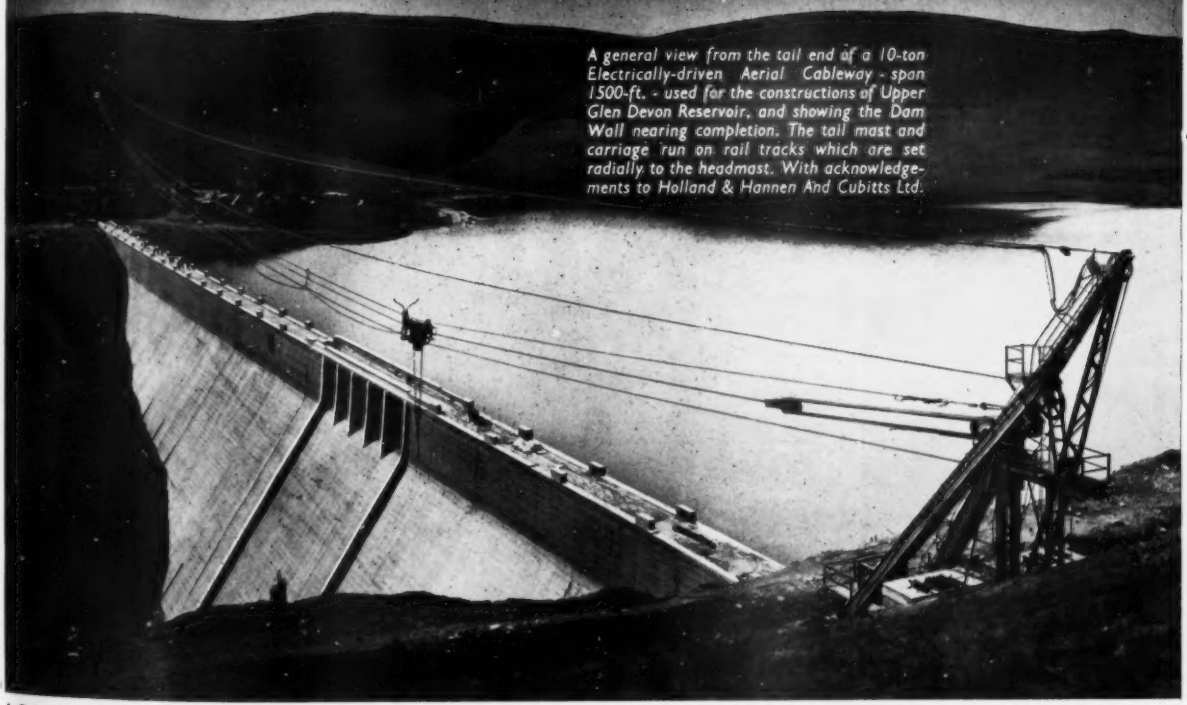

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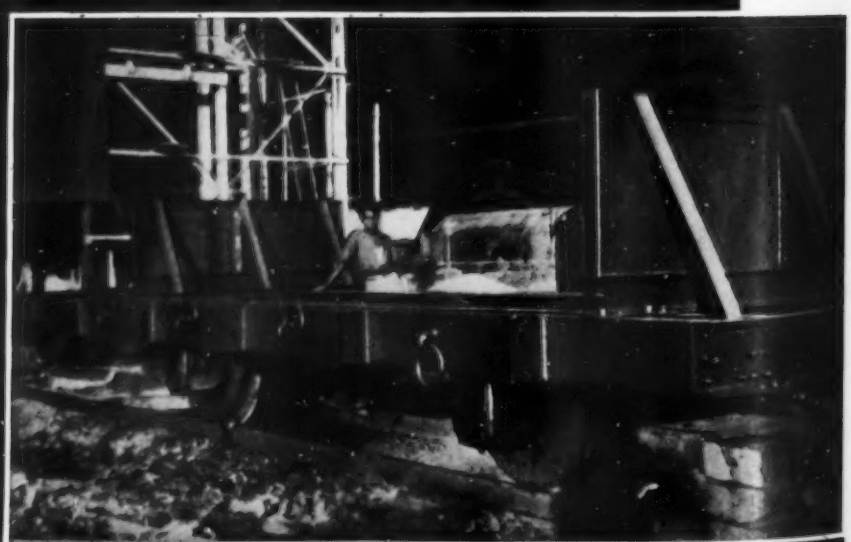

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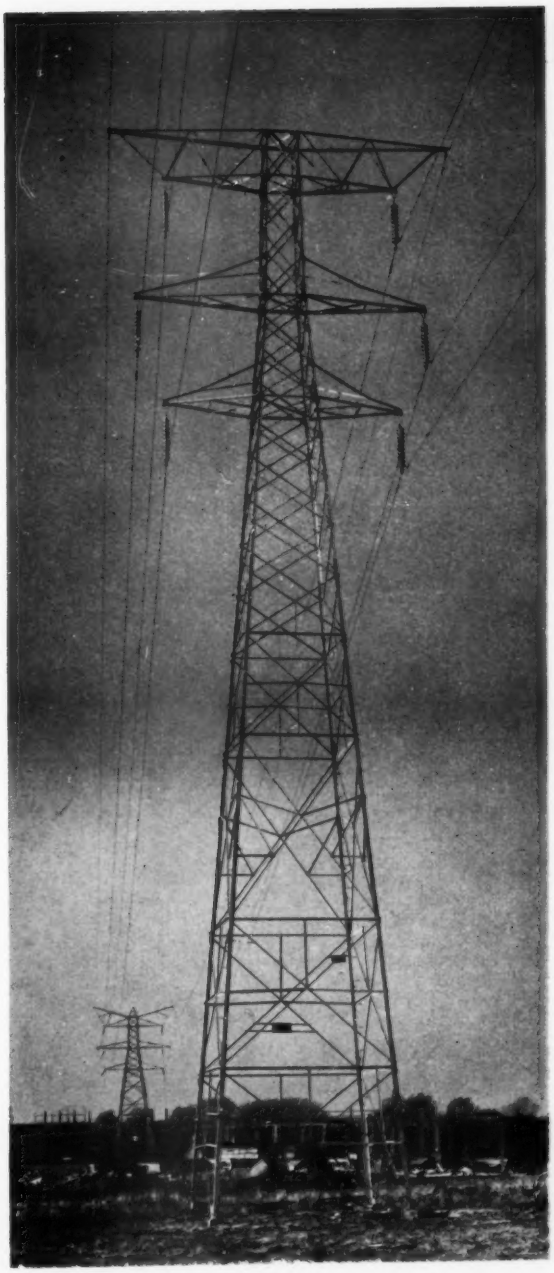

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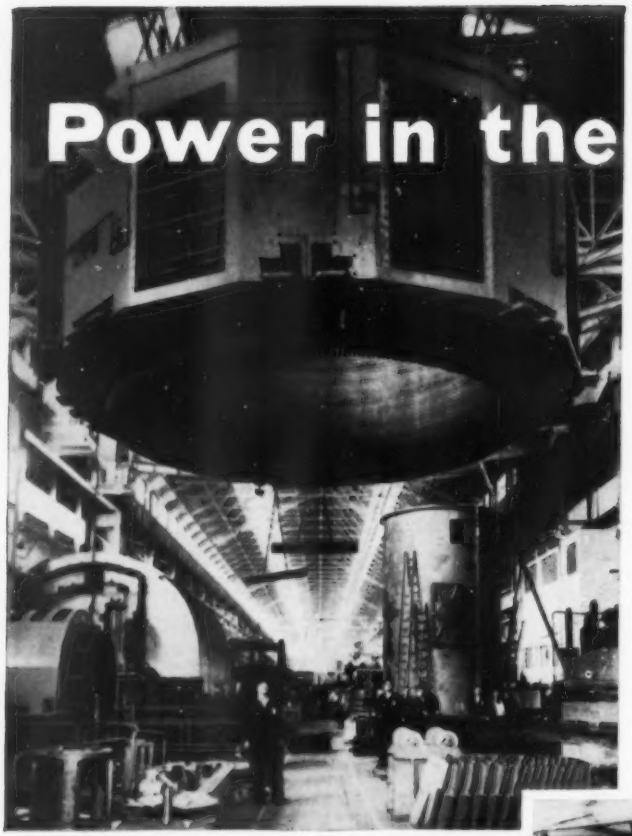

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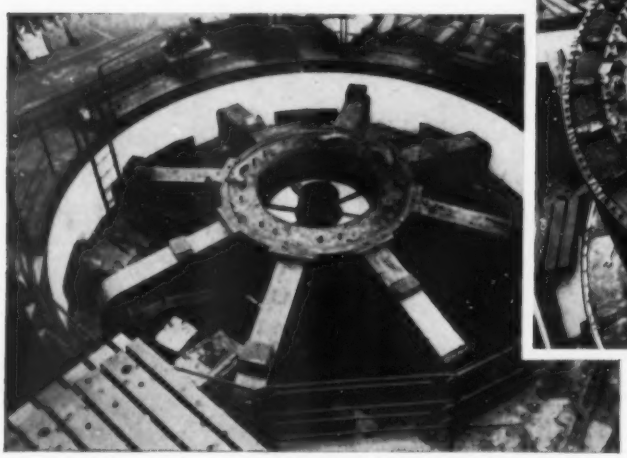
The rotor of the 75,000 kVA vertical generator.



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